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## MINERALOGY'S CONTRIBUTION TO OTHER SCIENCES AND TO INDUSTRY\*

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If, as Wentworth suggests, the position of geology among the sciences is an anomalous one, that of mineralogy is much more so. If geology is "a sort of peripatetic relative of the fundamental sciences, going the rounds of more respectable abodes," mineralogy may be looked upon as a more dependent relative characterized by a very little individuality. Geology may indeed be regarded as a daughter of physics and chemistry and a stepdaughter of zoology, inheriting many of its habits and methods of thought from its nearest relatives, but it possesses marked individual traits due to its travels abroad—away from the abodes of its family group.

Mineralogy, on the other hand, is mainly a laboratory science, and though perhaps more dependent upon chemistry and physics for its methods of action than is geology, it nevertheless possesses some individuality, which although less noticeable than that of geology, has led to results that have earned for itself an honored place in the family of sciences, in that it has contributed to the family points of view and methods of thought that have well repaid its relatives for the aid received from them.

Mineralogy can claim no methods of work or even conceptions that are distinctly its own, but neither can physics, chemistry nor zoology, except in small measure. The border lines between these sciences are very shadowy and are becoming less and less sharp as our knowledge of their fundamental conceptions becomes better known. Chemistry and zoology have borrowed from physics in order to explain some of their phenomena, and physics in turn has borrowed largely from chemistry, especially in the field of molecular philosophy. There are, however, certain fields of thought that are characteristically physical and others that are characteristically chemical, that are enough different from one another to be individualistic. Mineralogy, perhaps, depends more upon physics and chemistry for the tools with which it solves its problems, than do these

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sciences upon each other or upon mineralogy, but mineralogy has developed one phase of thought that is as distinctive for it, as have both physics and chemistry. For instance, crystallography was developed as the result of the study of minerals. It has shared this field with physics and chemistry to such an extent that one is apt to forget that mineralogy was responsible for its development.

Mineralogy is often considered as a branch of geology because it deals with the materials that make up such a large portion of the Earth's crust. But zoology and botany also contribute largely to the mass of materials composing the crust and have been active in producing a great part of the rocks of which it is made.

Of the two sciences geology and mineralogy, the latter is to be regarded, perhaps as the older. At any rate minerals were recognized as objects to be studied, earlier than was the crust of the Earth, and the name was certainly used before the name "geology," although F. D. Adams<sup>1</sup> has discovered that the word "geologia" was used by D. Aldrovandus in the title of one of his unpublished manuscripts listed in his will, written in 1605.

Because of their use as the sources of metals and as decorative materials, minerals have attracted the attention of mankind from the earliest time. Their early study, however, consisted merely of their description in general terms, so that other specimens might be identified in turn, and all classifications were based on superficial appearances. Later they were studied as chemical compounds, and it was not until attention was directed toward their forms that mineralogy became differentiated from the other sciences. So far as known, the first description of minerals was given by Theophrastus in about the year 315 B.C. The first known systematic treatment of them was by Albertus Magnus in his "De Mineralibus," written in the year 1262. In the 16th century Georgius Agricola published his book on the minerals of importance in mining; K. Gesner, in 1565, his systematic treatise on minerals; and Boethius de Boodt, in 1609, his volume on precious stones. The beginning of the study of crystal optics is marked by the researches of Erasmus Bartholinus on Iceland spar in 1669. The relation of chemistry to mineralogy was recognized by Wallerious in 1747 and by Cronstedt in 1758, but this relationship was not fully appreciated until some time later.

It was, however, not until after the publication of Rome de l'Isle's "Essai de Cristallographie" in 1772, in which he showed that the forms of crystals are characteristic of the substances that exhibit them, and the appearance in 1784 of Abbé Haüy's essay on the structure of crys-

<sup>1</sup> Adams, F. D., Further note in the earliest use of the word geology: *Bull. Geol. Soc. Am.*, vol. 44, pp. 821-826.



tals, which laid the groundwork for the development of the important laws of crystallography, that crystallized minerals became of great interest to chemists and geometers. It was then that modern mineralogy may be said to have been established as a distinct branch of study. With the invention of the reflecting goniometer by Wollaston in 1809, and his discovery of the laws of isomorphism and dimorphism, in 1819–21, and the discovery by Brewster, in 1818, of the close relation between the forms and the optical properties of crystals, the foundations of the science were stabilized. But as Browne<sup>2</sup> has well said "the boundaries of one science encroach upon the territories of others and it is in that fertile borderland where chemistry, physics, biology and other fields of knowledge overlap that the greatest discoveries are now being made." The worker in a given science, who, in his quest for truth, strays over into the field of another science is not stigmatized as an intruder, but is greeted rather as a welcome visitor.

Today I purpose to adventure into the provinces of scientists in other fields and with the help of a few illustrations call attention to the fact that mineralogy is largely a service science, contributing to other sciences and to industry, in return for some of the contributions received by it from them.

From the earliest days, as has been said, minerals have been gathered for their decorative value. Later they were sought as sources of metals and for other industrial purposes, and this search has been continued to the present day. Obviously it is unnecessary to dwell on the contributions made to the sciences and industry by the discovery of new minerals and by the study of the distribution of those of economic value, since the importance of these is generally recognized. It may be remarked, however, that in the course of this type of work, chemistry has been enriched by the discovery of tantalum by Hatchell in 1801, of palladium and rhodium in platinum by Wollaston in 1803 and 1804, of lithium in spodumene, petalite and other minerals by Arfvedson in 1817, and of thorium in thorite by Berzelius in 1825. Moreover, the attention of physicists has been called to the electrical and optical properties of tourmaline, Iceland spar and other minerals, and of geologists to the microscopic study of the mineral components of rocks and their alterations.

The discovery of the double refraction of Iceland spar was made by Bartholinus in 1669, of the electrification of tourmaline upon heating by Aepinus in 1762, and of the production of phosphorescence in fluorspar and certain other minerals by Pott in 1755, and before him by Wall in

<sup>2</sup> Browne, C. A., *Science*, vol. 84, p. 4, 1936.

1708 and by Du Fay in 1735. Wilson, in 1762, knew that tourmaline became electrified by rubbing, with a positive and a negative pole, like glass and certain gems, and Aepinus, in 1776, together with Bergman had learned that the pole which was positively electrified with rising temperature became negatively electrified as the temperature fell. Huygens, in 1678, described the two rays transmitted by Iceland spar as being unlike and as possessing properties different from those of ordinary light, but it was not until 1808 that Malus recognized the light as being like that reflected from window glass, which he called polarized, and directed the attention of scientists to the peculiar properties of this kind of light by constructing an instrument consisting of plates of reflecting glass for producing it, and using a crystal of calcite, or a second reflecting glass surface, to detect it. This gave a new tool to mineralogists, but it was not used by them until a more convenient method of producing polarization than was afforded by Malus's reflecting surfaces was discovered.

Seebeck and Biot, in 1813 and 1814, discovered that tourmaline also is doubly refracting, after Cordier in 1809 had observed that one of its refracted rays is absorbed. This knowledge was taken advantage of by Seebeck and Biot in the construction of their tourmaline polariscope—the familiar tourmaline tongs. This instrument, however, gives a polarized ray that is strongly colored and, consequently, is unsatisfactory for many of the purposes for which a polariscope might be used. Nevertheless, it was employed to study the polarizing properties exhibited by other minerals, but because of the color and weakness of the transmitted light its use was limited, and among mineralogists in general it found little favor. Even after Nicol, in 1828, invented his calcite prism, no attention was paid to the possibility of using the completely polarized colorless ray it produced in the study of minerals for thirty years. It was not until Sorby, in 1858, published his paper "On the microscopic structure of crystals" that mineralogists became impressed with the idea that polarized light offered them a new and convenient means of investigating crystallized minerals.

Soon after the means of producing polarized light became available, Brewster discovered that fluorspar and halite, which are normally non-polarizing, become doubly refracting under pressure, after Seebeck, in 1813-1814, had learned that glass, after being heated and then cooled rapidly, also showed double refraction. This observation of Seebeck's led to the process of annealing glass by slow cooling.

About this time also Biot, in 1815, Herschel, in 1820, and Brewster, in the same year, studied the rotation produced in a ray of light passing through quartz in the direction of its vertical axis—a phenomenon which



Fresnel had already, in 1817, denominated circular polarization—and found that the rotation was to the right, or to the left, in accordance with the presence of right- or left-handed forms on the crystals. The phenomenon, when studied in more detail, suggested the construction of instruments for measuring the amount of rotation produced by other substances, the most familiar instrument being the saccharimeter used to determine the strength of sugar solutions for the purpose of fixing the tariff rate that should be charged on imported cargoes of raw sugar.

The Nicol prism soon supplanted all other instruments for producing polarized light, since it yielded a colorless ray, but it could cover only a small area because of the impossibility of securing large crystals of Iceland spar, except at an enormous price.

The demand for a means of diminishing the glare from the headlights of automobiles approaching each other, suggested to Mr. E. H. Land a few years ago that the result desired might be accomplished by polarizing the light leaving the headlights and cutting it out by an analyzer in the windshield of the approaching car, or by analyzing goggles worn by its driver. The Nicol prism was not suitable for this purpose because of its small size, its expense, and its clumsy shape. In order that the method might be practical it was necessary that the polarizing medium should be capable of covering large areas and that it be comparatively cheap. These requirements were met by the invention of the film, known as "polaroid." This consists of a sheet of cellulose acetate in which are imbedded millions of tiny, doubly refracting dichroic crystals of herapathite, or sulphate of iodoquinine. The compound forms orthorhombic plates flattened parallel to the brachypinacoid. Of its two refracted rays produced when light is incident on this plane, the ray that vibrates parallel to the orthopinacoid (100) is almost completely absorbed, while that vibrating parallel to the base (001) is transmitted with a very faint olive-green tinge, which in very small crystals is not noticeable, and which, of course, is polarized. When the polarizing axes of the small crystals are uniformly oriented, as they are in polaroid, they produce the effect of a single large crystal. This polarizing film possesses great advantages over other polarizers in that it is flexible, mechanically stable, and is resistant to moderately high temperatures. Moreover, it can be made of a size to polarize over a large area. Because of these characteristics, besides destroying the glare of automobile lamps, the film may become a valuable aid in industry by reducing the glare from the surfaces of materials being inspected for imperfections, by making it possible to detect strains in models made up of transparent substances, and by offering a means of presenting three dimensional motion pictures in color. The use of polar-

ized light has been employed for some of these purposes in scientific laboratories, but its use has heretofore been employed as a working tool in industrial establishments to only a slight extent.

Recently the use of polarized light has also been called into service in the study of the moon. For the past 300 years astronomers have busied themselves mapping the surface features of the moon until now no part of that portion of its surface visible to us has been unexplored. They have attempted to explain the origin of these features but have been unable to do so because ignorant of the exact nature of their materials. The problem of ascertaining their nature has been assigned to a committee of which Dr. F. E. Wright<sup>3</sup> of the Geophysical Laboratory is chairman, in the expectation that if the composition of the moon's surface materials is discovered it may be possible to explain the origin of its physiographic features. Advantage is taken of the fact that the moon's face is made visible to us by reflected sunlight, and that the reflected light differs from direct sunlight in that it is partially polarized. By measuring the intensity of the light reflected from different areas, and its degree of polarization, it has been learned that, in general, the mountains and lighter areas of the moon reflect more light than is reflected from the smooth portions of its surface (the seas) and other dark areas, and that only about half as much is polarized. By measuring the amounts of plane polarization in light reflected by terrestrial materials and comparing the result with the polarization in the moon's reflected light, it is inferred with a strong degree of probability that the moon's material is like that of the light colored and porous substances occurring on the Earth, and that the probability is that it consists of acid volcanic ash and pumice. It is expected that with further detailed measurements of the nature of the light reflected from the moon it will be possible to ascertain with fair certainty what the lunar surface materials are, and how they are distributed on that part of the moon visible to us, and we then "shall be in a position to attack the problem of its physiography and the mode of formation of its surface features."

After Nicol's invention of the polarizing prism a means was at hand for obtaining polarized light by an instrument that could be applied to a microscope, and as a result the polarizing, or petrographic, microscope became available to students of minerals, though advantage was not taken of the aid that this instrument offered them until many years later. It is true that Ehrenberg in 1839 made use of the microscope in the study of chalk and tripolite, and in the examination of many other sedimentary rocks, and Brewster in 1824, and Nicol in 1828, had studied the fluid

<sup>3</sup> Wright, F. E., The surface features of the moon: *Scientific Monthly*, vol. 40, pp. 101-115, Feb. 1935.



cavities in the quartz of rocks, but none of these students felt any necessity in their work for the aid of polarized light. Zirkel, in 1862, began to teach the new methods of studying rocks by the optical investigation of their component minerals, and petrography was founded as a daughter of mineralogy. The close relationship of petrography and mineralogy is recognized by our Society in the description of the contents of its official publication, so I need not hesitate to consider petrography merely as a phase of mineralogy, and give credit to the latter for any contributions to science that have been made through the former—in other words, to consider petrography as one subsidiary of the holding company, mineralogy, the others perhaps being crystallography and mineralogical petrology.

It is hardly necessary to refer to the very intimate relationship existing between petrography and petrology. The latter is undeniably a phase of geology, whereas the former is as definite a branch of mineralogy. Petrography is a descriptive science, dealing with the composition of the solid crust of the earth, petrology is a philosophical science dealing with the origin and relationships of the components of the solid crust. A thorough knowledge of the petrography of rock masses is necessary before a study of their petrology is possible. For instance as, Barth<sup>4</sup> has remarked "without a knowledge of the mineral phases of metamorphic rocks it is impossible to discuss properly any theory of their origin or evolution." This is as true today as it has been in the past, and so far as we can see in the future it will always be necessary for petrography to help petrology in working out the laws governing the origin of rocks, and thus will always be intimately linked with geology through a gradation so uniform as to be with difficulty recognizable as a linkage.

The methods of petrography are based on the study of light transmitted through transparent crystallized bodies. But there are other bodies in rocks, and especially in those portions of rocks that function as ore deposits, which are opaque. These cannot be studied by transmitted light. They can, however, be viewed by reflected light, which as we have learned is always more or less polarized. Although engineers had been viewing through the microscope sections of steel and other metallic substances, in the study of their structure, especially with reference to the aggregation of their crystallized components, it was apparently Sorby who originated the method in his study of the structure of meteoric irons and described it to the British Association in 1864. Later mineralogists developed the methods and described the behavior of the ore-minerals when polished, etched and illuminated by reflected polarized light and thus laid the foundation for the study of the opaque minerals constitut-

<sup>4</sup> Barth, T. F. W., Petrology and metamorphism of the Paleozoic rocks: *Bull. Geol. Soc. Am.*, vol. 47, p. 779, 1936.

ing the greater portion of ore bodies, which now must be recognized and the relations between which must be known before the most efficient methods of ore-dressing may be planned. Thus mineralogy has been an aid to the smelting and refining industry and indirectly to the miner. In "Mineral Trade Notes"<sup>5</sup> we find the statement that "In ore-dressing the petrographical microscope is assuming an increasing important role because it furnishes the mineralogical composition of a given ore, the size, range, the structural characteristics and the degree of alteration of its components, and furnishes the technician with the information he needs to enable him to treat the ore with the maximum efficiency."

It is quite apparent to him who has followed the development of mineralography during the past 15 years, that economic geology could not have reached its present advanced stage had it not been for the enthusiastic work of mineralogically trained men on polished sections of ore-masses.

In the ceramic industry, also, the use of petrographic methods has been of great value in the examination of its products to discover imperfections with the purpose of remedying them, in the examination of raw materials with the view of selecting those substances of sufficient purity for the purposes desired, and in the study of reactions occurring between solids at high temperatures.

On the theoretical sides, the contributions of the workers in mineralogy, more particularly those of the Geophysical Laboratory in Washington, have been of inestimable importance in the understanding of the equilibrium conditions of the silica minerals, especially with reference to the manufacture of siliceous refractories, in the study of the effect of impurities in the raw materials upon the properties of the products made from them, and in the study of the action of clays and glasses on refractories. Among other contributions may be mentioned the recognition of mullite as a synthetic product, distinct from sillimanite, from which it had not hitherto been distinguished, a knowledge of the reactions of kyanite and andalusite at high temperatures which made possible their use in the manufacture of refractories and spark-plugs, and the suggestion that a mixture of forsterite and magnesite might be used for the making of basic brick for furnace linings.

Moreover, the study of the clay minerals by the aid of the microscope and x-rays, and the changes occurring in clays during firing, have done much to increase the understanding of those materials and to replace some of the old rule-of-thumb methods in the industry by scientific ones. It has been shown that clays composed of montmorillonite or beidellite

<sup>5</sup> *Mineral Trade Notes*, May 20, 1936, p. 34.



possess the best bonding properties for making synthetic molding sand, and that muscovite and talc are far superior to quartz and calcite for the coating of asphalt fillers, and thus have pointed the way to improve the quality of these products. It has been shown also that clays composed essentially of montmorillonite and beidellite exhibit to a high degree the ability to decolorize oils, and thus make it no longer necessary to use Fuller's earth for this purpose.

It has also been proven recently that the influence of acids and alkalis on the properties of clays is an effect due to base-exchange, the capacity for which rests in the clay mineral constituents and that different constituents have different base-exchange capacities. Heretofore it has been recognized that acids and alkalis influenced the properties of clays in different ways and to different extents, but the reasons therefore were not known.

Perhaps the greatest contribution to ceramics has been presented in the studies made by mineralogists and petrographers on the mineral composition of ceramic clays, and on the relation of mineral composition to ceramic properties, thus leading to a better understanding than formerly, of the factors controlling these properties. This understanding is helpful in processing clays to higher quality products, in the search for new supplies of raw material, and in providing a rapid method of predicting the ceramic properties of a clay before actual ceramic tests are made upon it.

The work of the members of the Geophysical Laboratory have also contributed greatly to the understanding of the reactions that take place in the manufacture of cement clinker, and in the production of refractories and of the slags in metallurgical processes. The results obtained by Rankin<sup>6</sup> and others in the study of the stability relations in the ternary system  $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$  have done much to clarify our knowledge of the nature of cement clinker. It has been shown that the chief constituents of a satisfactory clinker are  $2\text{CaO} \cdot \text{SiO}_2$ ,  $3\text{CaO} \cdot \text{SiO}_2$  and  $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ , and that any minor components (unless excessive in amount) that may be present in raw materials have little or no influence on the properties of the finished cement, except perhaps as diluters. With this knowledge at hand the manufacturer may select the material for the making of a cement that will meet the demands of the cement users with much more confidence than had hitherto been the case.

The inspection and comparison of the two ternary diagrams of calcium-iron and magnesium-iron silicates will show that when  $\text{CaO}$  is forced into ferrous iron silicates the melting temperature of the mixture

<sup>6</sup> Rankin, G. A. and Wright, F. E., *Am. Jour. Sci.*, second series, vol. 39, Jan. 1915.

is reduced, and therefore iron furnace slags containing lime are liquid, whereas, if  $\text{MgO}$  is added an opposite effect is produced, resulting in a raising of the melting temperature and a more viscous slag. Thus, also, since magnesium-rich materials are resistant to the fluxing action of ferrous silicates, it follows that linings of magnesite, or periclase, in an open hearth steel furnace absorb a large quantity of iron from the metal bath and form with it a solid solution that resists high temperatures. Likewise, olivine can be used as refractory blocks in steel cupolas because it can absorb 25% of  $\text{Fe}_2\text{SiO}_4$  and maintain a high melting point.

Some of the facts just related have been known to cement makers and metallurgists for a long while, but only as the result of experience. The reasons for them were not appreciated. It is no longer necessary to have the identical raw materials as were formerly used to produce a given product, since the engineer, knowing what happens in his oven or his furnace, is now able, within recognized limits, to adapt his processes to the nature of the raw materials he is able to secure and reach as good results, or even better, than did his predecessors with their traditional methods.

The consideration of base exchange referred to a moment ago, and so familiar to us in the operation of domestic water softeners, suggests that it may be the key to the explanation of the response of the soil to treatments for the purpose of making it more adaptable to plant growth, either by causing a change in its physical condition or by furnishing it plant food in which it may be deficient. For more than 50 years soil chemists have been studying the soil and have discovered many facts of interest concerning it. But in order to explain its character they have been compelled to make certain assumptions as to the nature of its components which latterly mineralogists working with the petrographic microscope and  $x$ -rays have shown to be untenable. Among these were the assumptions that kaolinite is the dominant component of its clayey portion, that zeolites are abundant in it, and that it contains colloidal material which was thought to be a mixture of amorphous aluminous and other hydroxides, and silica. It is now known through the work of several investigators, notably Ross, Hendricks, Fry, Grim, Kerr and others in this country, that the colloidal materials that are most effectual in base exchange are the micaceous-like minerals of the montmorillonite and beidellite series, and not zeolites, kaolinite, or the indefinite colloidal complex which had been regarded as one of the most active components of soils. These minerals (montmorillonite and beidellite) adsorb the plant foods and retain them in forms which can be utilized by plants, and by the exchange of calcium and magnesium for sodium in sticky soils render these more amenable to cultivation. Base exchange has now been



established on a mineralogical basis and the process cannot be studied except in relation to mineralogy, and in order to understand the cause of soil variations it becomes necessary to understand the mineral composition of soil colloids.

It may seem a far cry from petrography to archaeology but during the past decade, the methods employed in the study of rocks have been used to help archaeological students solve some of their special problems. For instance, they had assumed that since the material of the jade ornaments so widely distributed over the central portions of North America resembles so closely that from which were made the abundant ornaments so valued in China, Burma and other central Asiatic countries, that it must have originated in Asia, and that its existence in large quantity in Central America must be evidence that commercial connections existed between the Eastern Continent and this portion of the Western Continent, and that there was probably migration of peoples between them. Washington,<sup>7</sup> however, after a careful study of a series of jade ornaments from Mexico concluded that the jade from which they are made "differs from the usual jadeite of Burma and other sources of Chinese jade in two important particulars: the constant presence of large or considerable amounts of diopside with the jadeite in the pyroxene; and the presence of much albite in most of the series, either wholly in solid solution in the pyroxene, or partly so and in part separately crystallized." He suggests that the American jade shows such well marked general and serial characters as to be deserving of a special name and proposes "mayaite" to distinguish it from the more widely known Burman jade, the jades which contain little or no diopside or feldspar. "Purely jadeite jade," he states, "seems to be unknown from, or at least is of very rare occurrence in Middle America," and the conclusion is warranted that "the material of the Central American and Mexican 'jade' objects is of American and not Asian provenance." Although no American locality is yet known where mayaite occurs in situ he believes that it came "from either Mexico or Central America and that there are probably two centers of supply, both near the west (Pacific) coast, one probably in Oaxaca or Guerrero, and the other in Guatemala."

If this conclusion is correct there is no evidence that there was necessarily any commercial intercourse between Middle America and Asia at the time the jade ornaments were made.

Moreover, there is now being studied by petrographic methods the nature of the materials employed in the manufacture of ancient pottery, especially in the southwestern part of the United States, under the super-

<sup>7</sup> Washington, H. S., The jades of Middle America: *Proc. Nat. Acad. of Sciences*, vol. 8, No. 11, pp. 319-326, Nov. 1922.

vision of Dr. A. V. Kidder and Miss A. O. Shepard<sup>8</sup> in the Laboratory of Anthropology at Sante Fé, New Mexico, which promises to throw important light on the intercourse between pre-historic peoples in this district. Pottery is recognized as one of the most important sources of evidence for cultures antedating written records. It has been used to trace not only the migration of ancient peoples, but also to chart the paths followed by commercial intercourse. Heretofore, archeologists have depended mainly upon stylistic features to guide them to their conclusions. Recently, however, it has been suspected that further information might be gained by a study of the method of manufacture of the pottery found at different sites, which would lead to more definite results than could be obtained by stylistic studies alone. It was realized that if the nature of the raw materials used by the primitive potter could be discovered they might furnish better clues to the origin of the finished product than its shape, color, design, etc., because these features are known, in some cases, to be constant over widely spread areas. Examination by petrographic methods of thin sections and the powder of Pueblo and Mayan pottery fragments, and of the glazes used on them, has brought out the importance of the method as a means of determining the volume of trade between villages and centers of manufacture, where there is a diversity of geological formations within the areas concerned, and by comparing the results of the examination of pottery fragments from successive stratigraphic horizons within a given area or in a rubbish heap, has led to the dating of the relative time at which a given type of ware may have been introduced into a region, and to a knowledge of the development of pottery making as an industry.

Perhaps the most valuable contribution made to chemistry and physics in large part by mineralogists, aided however by chemists, mathematicians and physicists, has to do with the structure of crystals. Häüy, as the result of his early work, was led to suggest that crystals may consist of minute particles, having the form of the cleavage fragments of the minerals concerned, packed together in a regular manner to make up their crystal shapes. Later, when the conception of atoms and molecules had been established by the chemists, the molecule was substituted for Häüy's cleavage particles, and the crystal was imagined as made up of molecules equidistantly distributed along parallel lines in a net-like structure—or a space lattice—which may be pictured as consisting of three sets of parallel planes enclosing parallelopipeds, at the corners of which are placed the constituent molecules of the crystal. In

<sup>8</sup> Kidder, A. V., and Shephard, A. O., *Pottery of Pecos*, Vol. II, pp. 21-24, Yale Univ. Press, New Haven, Conn., 1936.



1850 Bravais showed that if this conception is accepted space can be partitioned into 14 space lattices—and Sohncke, in 1879, substituted “points,” or the centers of gravity of the molecules for the molecules themselves, and proved that all of the 65 point systems developed by him might be derived from the 14 space lattices of Bravais, by interpenetrating any one space lattice with one or more identical lattices, and proposed a definition of a crystal which is still acceptable to all crystallographers. After the discovery of the Röntgen rays, v. Laue in 1912, found, as was to have been expected, that crystals of rock salt acted as gratings reflecting the rays from atoms, rather than from molecules in such a way as to interfere and give rise to the now well known Laue diffraction patterns of space lattices. Then followed the  $x$ -ray spectra developed by the methods of W. L. Bragg—a discovery which, according to Klockman, resulted in the greatest advance made in physics and mineralogy since the beginning of the present century.

The experiments of Laue and Bragg furnished a means for the examination of a solid substance, the structure of which, hitherto, could be inferred only from certain facts of crystallography and certain phenomena that are dependent upon its surface skin reactions. It was soon learned that the structure of the solid (crystalline) body is due to the arrangement of its atoms relative to one another, and only indirectly to the arrangement of the atoms in molecules, or of the molecules with respect to each other. The results of the study indicated that the structural unit in most crystalline (solid) bodies is the cell, and not the molecule, as conceived from the study of gases and liquids, although it is possible that in some crystals, as in diamond according to Sir Wm. Bragg, the cell and the molecule may be coextensive, and in some others the cell may contain groups of molecules, comparable with those in gases and liquids, but which are much less strongly held together than are the atoms in the molecules.

The chemist has long recognized that the molecule possesses structure and that substances which consist of the same number of the same kinds of atoms but differ in their properties do so because of the different arrangement of these atoms in the molecule, and he has expressed their difference in his structural formulas. But the molecule is three-dimensional and the formulas have indicated the atomic arrangement in two dimensions only. The study of molecules in solutions can give no hint as to the arrangement of their atoms in the third dimension. It is necessary to get aid for the settlement of this problem from the study of the crystal cell.

The results of the study of crystals by  $x$ -ray methods has caused the abandonment of the old conception of the molecule as a particular group-

ing of atoms that is fixed for any one substance under all conditions, and the adoption of the new conception of the cell as the architectural unit of solid bodies. The molecule in the crystal is not always the same as when in a gas or liquid. "We even find some cases," says Sir William Bragg, "in which there is such a regrouping of the atoms that a new molecule may be said to have formed. There is always regularity in the arrangement within the crystal; but it is not strictly correct to say that it is an arrangement of the molecules unless the chemist will allow that his molecules can be altered." The conception of the cell in the architecture of solid bodies is an addition to the chemist's tools, which enables him to understand the way in which solids are constructed much more clearly than had hitherto been possible.

Another contribution of importance to chemistry is due directly to the discovery by N. Fuchs in 1815 that in the mineral gehlenite, which is essentially a calcium aluminum silicate ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ ), there is always more or less ferrous oxide, and that the greater the amount of iron in the compound the less is the amount of calcium in it, but that always the sum of the two is equivalent to the amount of either alone that would balance the silica and alumina present. In other words, he declared that the ferrous iron and the calcium, in this instance, constitute compounds with silica and alumina that crystallize essentially in the same forms, analogous to the potassium and ammonium phosphates and arsenates investigated by Mitscherlich in 1819 and called by him "isomorphous," and it was deduced from these observations that isomorphous compounds are capable of mixing in various proportions to form homogeneous crystals. In referring to the alums, later, Fuchs remarks that "sulphate of alumina forms, with ammonium, an alum just as well as with potash or with both these alkalies" and that "the potash can here be completely or partially replaced by ammonium or vice versa," and again in another statement he generalized to the effect that certain elements or groups of elements are capable of replacing partially, or entirely, other elements or groups of elements in compounds without introducing any considerable change in their crystalline forms. Constituents possessing this property were called "vicarious."

Not only did this discovery revolutionize the classification of minerals, but it also introduced the conception of the possibility of the replacement of one atom or group of atoms by an analogous atom or atomic group in crystalline mineral compounds without changing the plan of their atomic structure, and inferentially also in many other chemical compounds, a conception which is now universally recognized in the term "isomorphous mixtures."



Among the minor contributions of mineralogists to the chemists was the introduction to them by Cronstedt, in 1765, of the blowpipe and the establishment by Bořický, in 1877, of the microscope as analytical instruments. Although the blowpipe had been used in industry since very early days and its value in the detection of the more important components of mineral compounds had been recognized for some time in Sweden, it was not until Cronstedt's treatise had been translated into English by von Engeström, in 1770, that its importance to the analytical chemists was realized.

Similarly, before Bořický's time the microscope had been employed, in a minor way, in the testing of substances by the observation of the shapes of the grains of precipitates produced by their treatment with known reagents, but it was not until this worker systematized the methods used and applied them to the detection of the constituents of minerals that the practice was appreciated as a valuable means of recognizing the components in small quantities of substances. Behrens broadened the use of the process in 1894 and 1921, and in 1930-31 Chamot and Mason, in their great treatise, the "Handbook of Chemical Microscopy," refined it and secured for it the serious attention of chemists. It may be true that the chemists pay more attention to the color reactions of the substances being tested than do the mineralogists who depend more upon crystallized precipitates produced; nevertheless, the process must be regarded as having been developed originally by students of minerals.

In addition to the aid furnished to physics in the understanding of the structure of crystallized bodies it has been the good fortune of mineralogy, also through crystallography, to help, in some measure, in the perfection of electrical devices.

Haüy, in 1801, discovered that some minerals will conduct electricity and that others will not, and so divided them into two groups, conductors and insulators, and Ritter, in 1802, and Wartman, in 1853, found upon experimentation that monoclinic crystals in general are non-conductors. Muscovite was indicated as one of the non-conductors. Because of its ready cleavage into thin plates, its resistance to heat and the ease with which its sheets can be cut and punched, muscovite and to a less extent the amber mica, phlogopite, were found to be well adapted to serve as insulators. Great quantities of the two minerals are now required for the production of electric lamps and for the construction of electrical appliances that have become necessary to modern industry.

Further, when a non-conducting crystal with polar axes of symmetry (and a few others) is subjected to changes of temperature a charge of electricity will be developed on its surface, which, with rising tempera-

ture will be positive at one end of the polar axis and negative at the other, and with falling temperature will be reversed. Such crystals are said to be pyroelectric. The property was first discovered in tourmaline by Aepinus and Wilson independently in 1762, and was more precisely investigated by Bergman in 1766, though the phenomenon of electrification exhibited by minerals had been recognized 50 years earlier by other observers. Since, when a pyroelectric crystal changes its temperature it expands or contracts, it was natural to infer that the reverse might be true—that if compressed in the direction of a polar axis it might become charged with electricity in the same way as though it were being subjected to a falling temperature, and if, on the other hand, it were subjected to an electric charge it might change its shape. These inferences were found to be correct by P. and J. Curie and the facts were announced by them in 1880 and 1881.

The type of electric charge produced by compression is known as piezoelectric. It is exhibited by the same kinds of crystals that exhibit pyroelectricity, and the two phenomena are regarded as very closely related. Lippman, in 1881, indicated that we should expect electrification to alter the size and shape of such a crystal, and the Curies found this to be the case. By subjecting a thin plate of a pyroelectric crystal to a rapidly alternating electric field it is made to vibrate, i.e. to alternately expand and contract, and if the frequency of vibration of the current agrees with the natural frequency of vibration of the crystal plate the amplitude of the oscillation of the plate becomes relatively large. If, therefore, thin plates of quartz crystal are cut so that their broad faces are perpendicular to one of its polar axes, and these plates are subjected to alternate pulsating currents, they contract and expand alternately and so assume a rhythmic vibration which controls and forces into audio frequency the current transmitted to the radio receiving set.

Another characteristic of certain crystallized minerals, such, for instance, as galena and pyrite, is that when introduced into an electric current in contact with a metal they influence the current to flow much more easily in one direction between the surface of the crystal and the metallic contact than in the opposite direction. Thus when such a couplet of crystal and metallic contact is built into a wireless receiving set it causes "rectification" or the conversion of the type of alternating current in the radio receiving antenna into a pulsating unidirectional form that will cause a diaphragm to vibrate with a frequency which results in the production of sound waves. This property was made use of in wireless telegraphy and telephony and in the construction of early radio sets (crystal sets).



At present, however, the piezoelectric property of quartz plates is employed to control radio reception and force it into audio frequency, as has already been indicated.

In medicine the mineralogist has contributed very little in recent times. In the Middle Ages he offered a number of minerals to practitioners to cure various maladies, but with the exception of a very few they were of little value.

It will be recalled that the forerunners of modern chemists, the alchemists, up to the beginning of the 18th century, published accounts of the medicinal properties of metals and minerals. In the "*Pharmacopeia Medico-Chymica*" of Johann Schröder, for instance (1641), some minerals were listed as being dominated by the sun and, therefore, as having a good influence on humanity, others as being related to the moon and, therefore, being neutral in their influence, and others as being controlled by Saturn and, therefore, being inimical to mankind. Others were declared to be dominated by Mars or by Venus. To produce an effect on a patient a selected mineral was dissolved, distilled, decomposed or otherwise treated to produce a draught that was supposed to acquire the virtue of the mineral treated, which upon being swallowed it imparted to the patient. The hyacinth decoction for instance strengthened the heart, was a specific against convulsions, and when worn as an amulet it protected against the plague. The attempt to change the difficultly decomposable minerals into forms in which they could be prescribed to men led to experimentation and observation, and these processes to philosophizing, giving rise to the invention of theories, some of which influenced chemistry profoundly and initiated discussions which, when they were settled, had helped the science materially on its way to the construction of a firm foundation. Thus the remarkable J. J. Beeher, economist, adventurer in finance, alchemist, physician, etc., in 1669 issued his famous "*Physica Subterranea*" in which he discussed mineral bodies, classified them, investigated their properties and as a result declaimed against the Aristotelian philosophy, and gave an explanation of their constitution which was adopted later by G. E. Stahl (1660-1734) as a foundation for his phlogiston theory, which kept chemists busy discussing for a hundred years or more until it was disposed of by Lavoisier in 1783, thus clarifying chemical theory and giving a new and inspiring trend to the science.

Recently, however, in the study of the cause of silicosis the mineralogist has, by the study of the dust in certain manufacturing and mining industries, discovered that this dread disease is occasioned when the dust contains a considerable proportion of tiny quartz particles and in

this way has indicated the possibility of the prevention of the disease.

In another way medical practice has been indirectly helped through the study of the phosphorescence and fluorescence of minerals by mineralogists and physicists.

The property of phosphorescence in minerals had been detected by Pliny and later by Albertus Magnus, but the phenomenon attracted little attention until Cascariola, a cobbler and amateur alchemist, in 1602, discovered that barium sulphide became self luminous for a short time after exposure to light. Shortly thereafter, it was found that a number of other substances possessed this same property, and they were classed together as "phosphori", or light bringers, and the phenomenon became known as phosphorescence.

Fluorescence, which is closely allied to phosphorescence, differing from it principally in that the bodies exhibiting it emit their characteristic light only while under the influence of the exciting impulse, which may be light or some other form of radiant energy, was not observed until 1833 when Sir David Brewster described a phenomenon, which he called internal dispersion, in a solution of chlorophyl through which a ray of light was passed, and a little later announced that the same phenomenon had been observed also in fluorspar and in certain other minerals. About 20 years later Sir G. G. Stokes named it fluorescence.

In recent years the list of minerals exhibiting fluorescence under various kinds of light has been greatly extended and the nature of the light emitted from them has become their most important diagnostic property. Thus, natural gems are easily distinguished from artificial gem substitutes.

Moreover, since fluorescence is excited by  $x$ -rays and by some of the rays emitted by radioactive substances, screens coated with fluorescing mineral powder are in common use for detecting these rays. The most familiar of these screens is the fluoroscope employed by physicians in the examination of the bones and the internal organs of their patients.

Reference has already been made to the use of polarized light in the study of the composition of the Moon's surface material. Another astronomical field in which petrographers have been active has to do with meteors, which have generally been regarded as "remnants of cosmic materials employed in the formation of worlds"—a conception that is seriously considered in Lockyer's well known volume "Meteoritic Hypothesis," though it was based on little authentic knowledge of these bodies. During the past quarter century meteorites have been studied more critically than hitherto with the aid of the petrographic microscope by Sorby, Daubrée, Tschermak, Cohen, Meunier, Doelter and others



abroad, and by Farrington and Merrill in this country. Merrill<sup>9</sup> particularly examined many falls and as the result of his examination expressed views as to the origin of their structures and of their material, as we now find it. He concluded that their composition is not such as to indicate that the meteorites which have been described, consist of world-making materials like those of the earth, since the rocks of the earth are of a much more highly siliceous type than those of meteorites, unless the material of these represent an extreme phase of magmatic differentiation from a more acid magma, no trace of which has yet been found in any of our celestial visitors. He believed, however, that the structure of meteorites, and particularly the spacial relations existing between their metallic constituent and their siliceous ones, is such as to indicate that the former is not an original component but is later in origin than its siliceous neighbors, and that it was formed by the reduction of the ferrous chloride, lawrenceite, which occurs in varying, though small, proportions in nearly all meteorites, and which originally must have been present in many of them in large quantity. Their structure and the existence in them of ferrous chloride, which is common among volcanic products on the Earth, and the numerous rounded bodies known as chondrules led him to believe that meteorites are unmistakably volcanic products and can not represent an exploded planet or the residuals in the process of world-building.

While, perhaps, no satisfactory conclusion has been arrived at with respect to the origin of meteorites, the field has been cleared for a further attack on the problem and we have a better idea now than was formerly the case, as to the phenomenon to be explained.

Mention has already been made of the help given to geology through the use of the petrographic microscope in the study of the nature of rocks and their origin, and by the metallographic microscope in the study of ores. There are other ways also in which the cooperation of the mineralogist has been of benefit in the solution of the geologist's problems. For instance, through the identification of the heavy mineral series in different beds of sedimentary rocks, it has been possible in some cases to work out their relative stratigraphic positions, and in others to discover the sources of their components.

Moreover, there are certain minerals, especially those containing uranium and thorium, and other elements of large atomic weights that are constantly and continuously emitting radiations as a result of the spontaneous disintegration of their heavy elements into other elements

<sup>9</sup> Merrill, Geo. P., Composition and structure of meteorites: *U. S. Nat. Museum, Bull.* 149, 1930.

of lower atomic weights, with the separation of helium, which is emitted as  $\alpha$  rays. The resulting newly formed elements are themselves in turn radioactive, and successively undergo further disintegration with the ultimate formation in all cases of stable forms of lead that differ from ordinary lead in their atomic weights.

The study of the pleochroic halos surrounding radioactive particles embedded in biotite and other minerals indicates that the rate of disintegration of the most important radioactive minerals has been uniform since the earliest geologic time, and, consequently, that a determination of the quantity of the lead and helium accumulated in the disintegrating compounds will give us a measure of their age and of the time that has elapsed since the rocks in which they occur were formed.

It is true that the discovery of radioactivity was first announced by Becquerel, in 1896, and that its significance was developed later as the result of the investigation of numerous other physicists, nevertheless the application of the knowledge thus acquired to the determination of the ages of rocks has been made mainly by mineralogists and geologists with a mineralogical training, and thus may be justly regarded as aid given by mineralogy to the solution of the problem of determining not only the relative ages of rock formations, but as well in many cases their actual ages.<sup>10</sup>

Since, we are all familiar with the many ways in which mineralogy has come to the help of geology, especially through crystallography and petrography, it is unnecessary to follow this phase of our subject any farther. The two sciences are so closely interwoven along portions of their borders that it is almost impossible to delimit their fields.

In international politics mineralogy is also beginning to play a part. Since the World War it has been evident that the most fertile cause of strife between nations is the necessity of those nations that are over populated to seek either more land to which their surplus population may be sent to relieve the pressure on their resources, or to increase their resources and become more industrialized so that that portion of their surplus population which declines to emigrate may be kept busy and contented. The development of industries, however, depends very largely upon mineral resources. If these are not present in sufficient quantity to furnish a country the raw materials upon which a large portion of its industry must depend, it is thought necessary, in order that it may live, to seek these resources outside of its own boundaries. Germany, Italy and Japan furnish illustrations of countries which are restless because of their great lack of mineral resources within their own boundaries. In the

<sup>10</sup> The age of the Earth: *Bull. Nat. Research Council*, No. 80. Washington, D. C. 1931.



past, so long as there were potential sources of minerals in districts that were not already controlled by powerful influences it was necessary only to send out expeditions and take possession of them. At present, however, this procedure is not so easy as there are few areas of potential mineral resources that are not under the watch of the great powers, since there is no country, as the World is now organized, self-sufficient in its mineral resources. According to Sampson<sup>11</sup> the United States controls 34.1% of the World's mineral resources and the British Empire 21.3%, and yet neither of these areas contains all the minerals necessary to satisfy its demands if it were completely blockaded.

In recent years economic geologists, whose training is largely mineralogical, have been studying closely the distribution of the present and the potential mineral resources of the World in the hope that such a study may result in economic readjustments that will remove the pressure which in the past has been an excuse for engaging in war.

Finally, mineralogists have suggested a new concept in philosophy through the proposal by Goldschmidt,<sup>12</sup> Palache and Peacock of a modification of the laws of crystallography which they call the law of complication, based on the two hypotheses, (1) that a crystal is a rigid system of like and similarly oriented particles, and (2) that every crystal face is a plane normal to a force of attraction exerted from the crystal's center. As a result of these forces, and in consequence of their different magnitudes a certain face predominates on each crystalized substance, its position being determined in accordance with the parallelogram of forces, and its node (the projection point of its face-normal in the gnomonic projection) is regarded, likewise, as the principal one for the crystal and is given the symbol 1, which serves as the unit from which other nodes are measured. It is assumed, however, that the entire magnitudes of the forces are not exerted to produce this resultant, but that these principal forces divide into aliquot parts, normally in halves, one half of each principal force acting to produce the resultant which determines the face with the node 1, and the remaining halves combining to give the resultant forces determining faces with nodes  $\frac{1}{2}$  and 2. "Similarly the successive combinations of halves of the remainders of the principal forces with halves of the newly formed resultants give further resultants determining the positions of faces with the nodes  $\frac{1}{3}$ ,  $\frac{2}{3}$ ,  $\frac{3}{2}$ , and 3, besides the two limiting nodes 0 and  $\infty$ . Thus the node symbols as given on opposite sides of the symbol 1 are reciprocals of one another. It is

<sup>11</sup> Sampson, E., Mineral commerce and international relations: *Jour. Franklin Inst.*, vol. 221, No. 1, January 1936.

<sup>12</sup> Peacock, M. A., *Am. Mineral.*, vol. 17, 1932, p. 317, and a criticism by Buerger, M. J., *Ibid.*, vol. 21, 1936, p. 702.

impracticable to discuss at this time the reasoning employed in establishing the law. It is enough to state that Goldschmidt has applied the conception to the relative vibration periods of the notes of a major scale in music, and on it is said to have built up an elaborate system of harmonic analysis. He has also applied it to the relative wave lengths of the most prominent Fraunhofer lines of the solar spectrum. The relative distances of the planets from the Sun also complies with the Law of Complication, provided the major and the minor planets are considered separately, as do also the distances of the satellites of Jupiter and of Uranus, measured from their mother planets. This relation led Goldschmidt to the theory that groups of cosmic bodies forming complication series were each generated in distinct epochs. He believed that the Law of Complication underlies other groups of natural appearances, and that that development of the manifold from the simple, by complication, is a universal process.



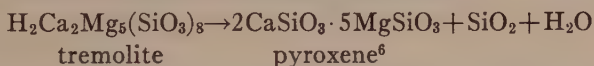
THE REGENERATION OF AMPHIBOLES FROM THEIR  
MELTS AT NORMAL PRESSURE

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## I. INTRODUCTION

E. Mitscherlich, P. Berthier and G. Rose have stated that amphiboles when fused do not recrystallize from their melts; instead pyroxenes<sup>1</sup> are formed. Analogous observations were also made by C. Doelter and E. Hussak (15), A. Becker (9), F. J. Loewinson-Lessing(7)<sup>2</sup> and others. These observations tend to support the view that amphiboles and pyroxenes are heteromorphous varieties of one and the same substance. Such a view could be held only as long as the real rôle of "water" in amphiboles had not been explained, and consequently the principal difference between the minerals of the amphibole group and those of the pyroxene group still remained unknown.

More recently much has been accomplished by B. Gossner (16, 17), W. Kunitz (26) and B. Warren (36, 37)<sup>3</sup> leading toward the correct view concerning the constitution of the amphiboles. The latter determined the fine structure of certain amphiboles by means of x-rays, dispelling all doubts as to the rôle of H<sub>2</sub>O in amphiboles. The experiments of the quoted authors proved that water is an unfailing constituent of amphiboles and enters their crystal lattice in the form of OH-groups.<sup>4</sup> The experiments of E. Posnjak and N. L. Bowen (30) show that the chief part of the H<sub>2</sub>O is eliminated from the crystal lattice at one time, at the high temperature of about 900°.<sup>5</sup> They state that in the process of heating the amphibole (tremolite in the given case) it decomposes in accordance with a reaction of the following type:



<sup>1</sup> On the basis of observations in nature, G. Rose (32) supposed that rapid cooling tends to prevent the crystallization of amphiboles and that with a slow cooling of the melt the amphibole must regenerate.

<sup>2</sup> F. J. Loewinson-Lessing acknowledged the important part played by H<sub>2</sub>O in the formation of amphiboles and carried out some experiments (which were unsuccessful) with the passing of aqueous vapors above the melt during crystallization.

<sup>3</sup> One of the works (on the structure of anthophyllite) was published by Warren together with D. J. Modell (38). Concerning the constitution of amphiboles see also the article of H. Berman and E. S. Larsen (10).

<sup>4</sup> See also the roentgenographic determinations of F. Rodolico (31).

<sup>5</sup> See also the investigations of Kôzu, Ioshiki and Kani (24).

<sup>6</sup> According to N. L. Bowen (11) it must be a member of the series of solid solutions: diopside-clinoenstatite. But against this argument objections are raised, see for instance D. P. Grigoriev (21).

That is to say: while in the process of heating, the amphibole decomposes with the formation of pyroxene, silica and aqueous vapor. According to C. Doelter and E. Hussak (15) hornblende decomposes at a high temperature and produces augite, or olivine, and magnetite (and  $\text{H}_2\text{O}$ . Authors). According to Kôzu and Ioshiki (23), hornblende investigated by them melted at  $1200^\circ$  with the formation of crystals of rhombic pyroxene (?) and magnetite ( $\text{H}_2\text{O}$  is eliminated at a lower temperature). It is quite evident that in the fusion and crystallization of anhydrous melts no amphibole would form; synthesis of minerals of this group from dry melts is likewise impossible [N. L. Bowen and Posnjak (12)].

Fusion of amphibole under pressure in the presence of  $\text{H}_2\text{O}$  (conditions under which regeneration would take place) has not, as yet, been performed.

Recently D. P. Grigoriev (3, 19) and D. P. Grigoriev and E. W. Isküll (22) succeeded in obtaining amphiboles at normal pressure by experimenting with fluorine-bearing silicate melts.

Fluorine escapes from these melts only in part (not more than half of the primary content). It is present in these melts in all cases in a quantity sufficient for the building of molecules of minerals of the amphibole and mica groups, which crystallize from them.

In the crystal structure of amphiboles and mica obtained in such a manner, fluorine atoms occupy the spaces ascribed previously to OH-groups.<sup>7</sup> That is, there form fluorine-amphiboles and mica, which are known from nature.<sup>8</sup> The artificial production of amphiboles from silicate fluorine-bearing melts shows the methods to be chosen in order to regenerate amphiboles from their melts. Obviously the removed  $\text{H}_2\text{O}$  must be replaced by fluorine that remains partly in the melt.

Actually, not quite the same mineral that was melted would be regenerated (fluorine amphibole instead of hydroxyl or hydroxyl-fluorine amphibole) but, after all, the problem of the regeneration of amphiboles from their melts at normal pressure<sup>9</sup> is solved in principle.

<sup>7</sup> In the mica, obtained by D. P. Grigoriev (4, 18) the fluorine content is 2.59%. E. F. Alexeeva and A. K. Boldyrev, who investigated this artificial mica by means of  $x$ -rays, supposed that OH in it is replaced not only by F, but also by OK-groups (instead of F, which is present in insufficient quantity). F. Machatschki (28), however, finds that in this case the lack in F is supplied only by oxygen.

<sup>8</sup> That the pure fluorine mica exists, one can be persuaded by examination of chemical analyses in Doelter's *Handbuch d. Mineralchemie*, Bd. II, 2. The complete replacing of OH by F in mica is well seen in the diagram of compositions of magnesium-iron-mica, which has been plotted by D. P. Grigoriev (4). The amphibole with large content of fluorine was described by J. Morozewicz (29).

<sup>9</sup> The hydrothermal synthesis of amphibole at low pressure was recently accomplished. See publications of K. H. Scheumann and W. Lüdke (27, 34, 35).



In order to regenerate amphiboles from their melts we attempted to fuse amphiboles with the addition of fluorine compounds. At the same time, in order to compare the results obtained, we fused amphiboles without such additions. Fusion was carried out in a cryptole furnace in graphite crucibles, at a temperature of about 1350°. The weight of each sample in all our experiments was 20 grams.

## 2. THE FUSION OF AMPHIBOLE FROM ILMEN MOUNTAINS

Hornblende found in veins in the Ilmen Mountains has been described by D. S. Beljankin (2). Its analysis, according to him, is as follows:

SiO <sub>2</sub>	49.72
TiO <sub>2</sub>	0.47
Al <sub>2</sub> O <sub>3</sub>	4.78
Fe <sub>2</sub> O <sub>3</sub>	4.48
FeO	5.66
MnO	0.38
MgO	14.08
CaO	12.73
Na <sub>2</sub> O	2.93
K <sub>2</sub> O	1.33
F	1.14
H <sub>2</sub> O	1.33
	<hr/>
	99.93

Calculating by Warren's method we arrive at the following formula:<sup>10</sup> (OH,F)<sub>1.98</sub>(Ca,Na,K)<sub>2.9</sub>(Mg,Fe'', Fe''', Al, Ti)<sub>5</sub>(Si,Al)<sub>8</sub>O<sub>22</sub>.

This amphibole may be classified among the common hornblendes and approaches the tremolite type.<sup>11</sup>

Under the microscope the mineral shows a pale green color with pleochroism: N<sub>g</sub>=pale bluish green, N<sub>m</sub>=green, and N<sub>p</sub>=yellowish green; absorption N<sub>g</sub>>N<sub>m</sub>>N<sub>p</sub>.

The elongation of the crystals is positive. The cleavage, typical for amphiboles, is clearly seen. The indices of refraction (determined by the immersion method) are:

$$\begin{aligned} N_g &= 1.635 \pm 0.003, \\ N_m &= 1.622 \pm 0.003, \\ N_p &= 1.614 \pm 0.003, \\ N_g - N_p &= 0.021. \end{aligned}$$

$$\text{Extinction angle } N_g \wedge c = 22^\circ; 2V = +70-75^\circ.$$

According to these data the amphibole is classed as a pargasite.

<sup>10</sup> Aluminum was distributed between the groups of elements of magnesium and silicon in the following manner:  $\frac{2}{3}$  were added to Mg and  $\frac{1}{3}$  to Si.

<sup>11</sup> Compare the division of amphiboles into types by H. Berman and E. S. Larsen (10).

*(a) Dry fusion.*

The fused powder of the amphibole hardens to a granular mass (grain size up to 2 mm.). The color of the melt on fracture surfaces is gray. At the bottom of the melt, where the melt is adjacent to the crucible, globules of iron, that are reduced from the melt to a metallic state, are seen.

In a microscopic examination the melt appears to consist wholly of pyroxene crystals, which are colorless and have the form of thick tablets. The cleavage proper to pyroxenes is clearly seen. The elongation of the

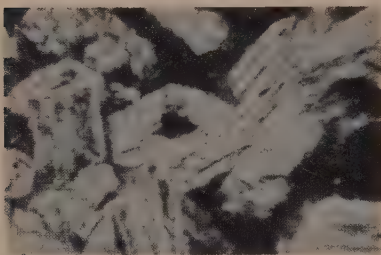


FIG. 1. The regenerated amphibole. One crystal is normal to [001].  $\times 150$ .

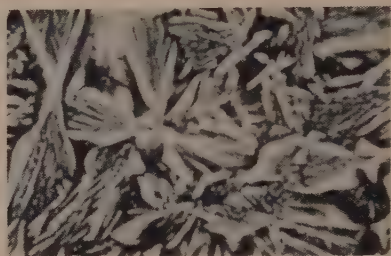


FIG. 2. The regenerated amphibole showing skeleton-growth.  $\times 65$ .

crystals is positive. The indices of refraction, determined also by means of the immersion method, are:

$$N_g = 1.664 \pm 0.003,$$

$$N_m = 1.655 \pm 0.003,$$

$$N_p = 1.652 \pm 0.003,$$

$$N_g - N_p = 0.012.$$

$$\text{Extinction angle } N_g \wedge c = 40^\circ, 2V = +60^\circ.$$

*(b) Fusion with fluorine.*

We had at our disposal only one fluorine compound suitable for our experiments, namely, calcium fluoride. Therefore, the amphibole was fused with 5% (by weight) of calcium fluoride. Thus 2.43% F and 2.57% Ca were introduced into the melt. The powder of amphibole and  $\text{CaF}_2$  were carefully mixed and then fused in the manner described above.

The melt thus obtained appeared crystalline and had a radiating structure. The maximum size of a single crystal was 3 mm. The color of the melt was pale gray, slightly greenish. In parts adjacent to the crucible globules of reduced iron were formed.

Under the microscope, from the general aspect and character of the cleavage (Fig. 1) the product obtained is clearly an amphibole.

The elongated crystals of the mineral form radiating aggregates.



In some areas of the thin sections of the melt, not entire crystals, but only skeletons of amphibole crystals can be seen (Fig. 2). The spaces between the crystals are filled with a dark opaque substance.

Under the microscope the amphibole is colorless. The elongation of the crystals is positive. The indices of refraction (determined by means of the immersion method) are:

$$N_g = 1.603 \pm 0.003,$$

$$N_m = 1.590 \pm 0.003,$$

$$N_p = 1.586 \pm 0.003,$$

$$N_g - N_p = 0.017.$$

$$\text{The angle } 2V = +55-60^\circ, \text{ extinction angle } N_g \wedge c = 17^\circ.$$

According to these data the newly formed amphibole differs greatly from the original mineral. Particularly striking is the difference in the indices of refraction.

The changes in the properties of the amphibole are probably due to the following circumstances:

1. Reduction of nearly all the iron present in the hornblende to metal. The newly formed amphibole is poor in iron.
2. Replacement of the eliminated Fe by Ca, which was introduced as  $\text{CaF}_2$ .
3. Total replacement of OH by F.
4. The possible elimination of some oxides from the melt at high temperature (e.g., those of the alkalis).

The reduction of the Fe content, as is known, must decrease the indices of refraction and birefringence; this may be observed in the newly formed amphibole. The same holds true of F, as shown by N. L. Bowen and J. F. Schairer for the synthetic amphiboles that they have obtained (13).<sup>12</sup> The action of Ca is as a rule, not very strong. The rôle of alkalis is in this case not definitely established.

### 3. THE FUSION OF OTHER AMPHIBOLES

In order to convince ourselves that besides the thoroughly investigated amphibole from Ilmen Mountains, other amphiboles are also liable to regeneration, we performed some fusion experiments with two other amphiboles: (1) an amphibole from Sliudjanka collected by D. P. Grigoriev in the year 1931 and which probably approaches pargasite, (2) an amphibole from Chertanysh (near Miass, Ural Mts.) which has been labelled in the Mining Museum under the name of actinolite (No. 808-3 of the fundamental collection).

The fusion of these amphiboles, without additions, leads to the forma-

<sup>12</sup> Cf. also the statements of W. Kunitz concerning the magnesium-iron mica. See also the data of D. P. Grigoriev (4).

tion of pyroxenes that, in optical character, resemble those described above. Fusion with 5%  $\text{CaF}_2$  resulted in the production of an amphibole and the same dark opaque substance which had been observed in the melts of the amphiboles from the Ilmen Mts.

We shall not describe the fused products of these amphiboles as they present nothing new in comparison with the results of the first experiment. They interest us insofar as they confirm the correctness and importance of the methods we have chosen for the regeneration of amphiboles.

#### 4. X-RAY STUDY

From the powder of one of the specimens of regenerated amphiboles ("Amph-5") *x*-ray diffraction patterns have been obtained by V. I. Mikheev. The *x*-ray study was carried out in the Roentgenographic Laboratory of the Mining Institute.<sup>13</sup>

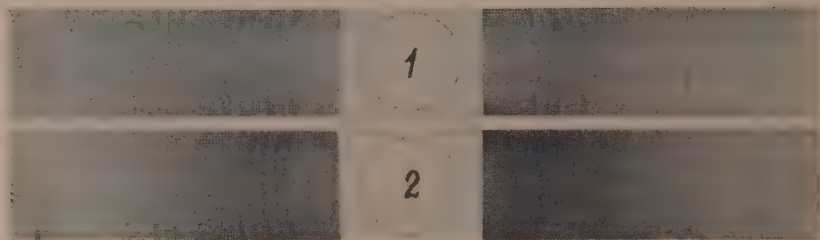


FIG. 3. X-ray diffraction patterns of natural (1) and regenerated (2) amphiboles.

The *x*-ray diffraction pattern of "Amph-5" is shown in Fig. 3 (2), and Fig. 3 (1) shows the pattern obtained from the natural amphibole from the Ilmen Mts. The latter pattern has been obtained from V. N. Doobinina's diploma work.

Pattern "Amph-5" shows 44 pairs of lines. The diffraction pattern obtained from natural amphibole shows 47 pairs of lines. The spacings between the corresponding pairs of lines of these patterns are identical. The relative intensities of the lines coincide in 39 cases; some deviation in five cases may be explained as due to the difference in the chemical composition of the newly formed amphibole in comparison with the natural amphibole (in no case was the position of a line changed but only its intensity). The absence of some lines in the patterns of the artificial amphibole in comparison with those that may be observed in patterns of the natural mineral, is probably due to the conditions of exposure. The

<sup>13</sup> X-ray diffraction patterns were obtained with  $K\alpha\beta$  radiation of iron by means of a Hadding tube. For calibration the powdered "Amph-5" was mixed with NaCl.



complete identity of the patterns of the natural and artificial amphiboles is well observed in Fig. 3. Hence the  $x$ -ray patterns confirm the conclusion that the newly formed mineral is truly an amphibole and that the structures of natural and artificial amphiboles are wholly identical.

## 5. CONCLUSION

Thus our experiments show:

(1) That only pyroxenes (monoclinic) crystallize from the dry melts of the investigated amphiboles.

(2) That amphiboles crystallize from their melts with fluorine additions, but they have their chemical composition somewhat altered.

(3) That to produce amphiboles from their melts the presence of fluorine (or OH) is required. This had formerly been shown by N. L. Bowen and E. Posnjak, but only inferentially.

(4) That fluorine acts in the melts the same way as the OH-group does, and occupies its space in the crystal structure of the amphiboles that crystallize from these melts.

(5) That our hypothesis regarding the possibility of replacing OH by F has been fully verified by experiments with silicate melts.

In conclusion it must be noted that fusion of amphiboles with fluorine additions had already been performed by C. Doelter (14) in 1888. According to him the fusion of alumina-bearing amphiboles with NaF and  $MgF_2$  gave as a result magnesium-mica, and similar fusions of amphiboles which contained no alumina lead to the formation of augite and olivine. C. Doelter added the fluorine compounds in very large quantities (particularly  $MgF_2$ ). Hence it becomes obvious why our experiments give different results. It is likewise true that the purpose of the experiments of C. Doelter was quite different, namely, the artificial production of mica.

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# PETROGRAPHY OF SOME ROCKS FROM THE SOUTH ORKNEY ISLANDS AND THE ANTARCTIC ARCHIPELAGO

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## INTRODUCTION AND ACKNOWLEDGMENTS

There are 294 specimens of Antarctic rocks and minerals in the collections of the University of Michigan. By the Spring of 1935, 178 specimens from six of the eight Antarctic expeditions represented, had been studied petrographically and the results published. There remained 116 rocks and minerals, collected by the Scottish National Antarctic, 1902-1904, and the Swedish Antarctic, 1901-1903, Expeditions to be examined microscopically. A project grant from The Geological Society of America and a grant-in-aid from the Society of the Sigma Xi have made this research possible. Grateful acknowledgments are due to Professors Laurence M. Gould, William H. Hobbs, Walter F. Hunt, and Chester B. Slawson, and Mr. W. L. G. Joerg for their interest shown in this investigation.

Dr. R. N. Rudmose Brown, of the University, Sheffield, England, furnished, through exchange of material with the University, nine duplicate specimens obtained from the South Orkney Islands by the Scottish Expedition. Dr. Gregori Aminoff, of the Mineralogical Department, Riksmuseet, Sweden, contributed, also through exchange, 107 duplicate specimens collected from the Antarctic Archipelago by the Swedish Expedition.

Figure 1 is a sketch map of Antarctica showing the location of the South Orkney Islands and the Antarctic Archipelago. Figures 2 and 3 are sketch maps of the South Orkney Islands, and of the northern region of the Antarctic Archipelago.

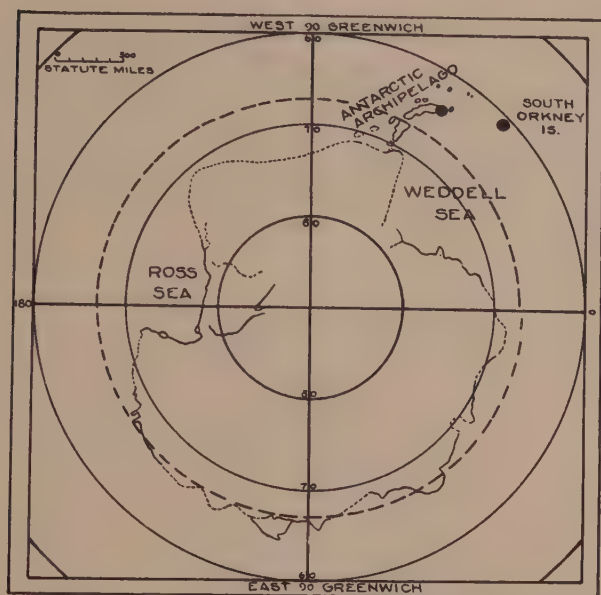


FIG. 1. Sketch map of Antarctica showing locations where specimens were collected.

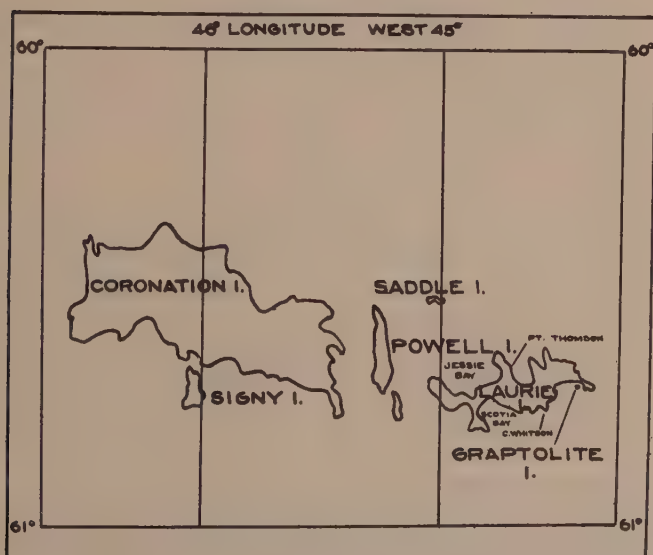


FIG. 2. Sketch map of the South Orkney Islands (after Sörlle).

Nineteen of the 114 thin sections examined had their constituents determined quantitatively. In traversing each thin section on an average of 16 times, with the improved Wentworth recording micrometer, an aggregate distance of 42,889 units was measured. The qualitative results of the study of the thin sections of the South Orkney rocks are recorded in Table I. The qualitative and quantitative results of the examinations of the specimens from the Antarctic Archipelago are recorded in Tables II, III, and IV.

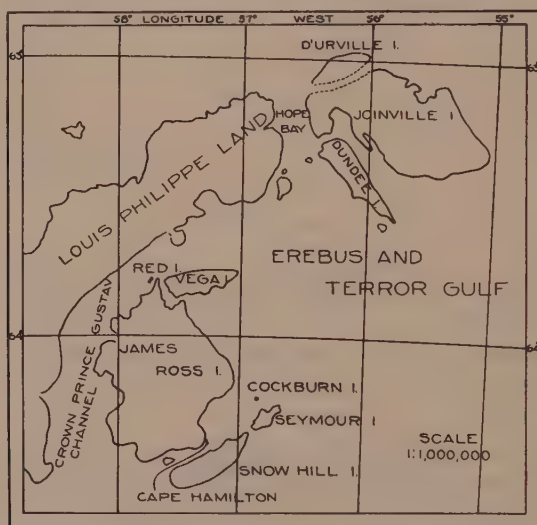


FIG. 3. Sketch map of the northern region of the Antarctic Archipelago (after Nordenskjöld).

#### SOUTH ORKNEY ISLANDS

The South Orkney Islands are located in about Latitude 61° South, Longitude 45° West, and are composed of two large islands, Coronation and Laurie; two smaller islands, Powell and Signy; and a large number of very small islands and rocks. Bruce<sup>1</sup> made an accurate and detailed map of Laurie Island in 1903. A recent map of the South Orkney Islands has been prepared by Sörllé.<sup>2</sup> John<sup>3</sup> reports that a complete survey of the

<sup>1</sup> Bruce, W. S., Outline map of Laurie Island: *Scottish National Antarctic Expedition, Report of the Scientific Results of the Voyage of S. Y. "Scotia" during the years 1902, 1903, and 1904*, Physics, vol. 2, 1907.

<sup>2</sup> Høltedahl, Olaf, On the geology and physiography of some Antarctic and Sub-Antarctic Islands: Scientific Results of the Norwegian Antarctic Expeditions, 1927-1928 and 1928-1929, *Det Norske Videnskaps-Akademi i Oslo*, No. 3, p. 100, 1929.

<sup>3</sup> John, D. D., The Second Antarctic Commission of the R. R. S. Discovery II: *Geogr. Journ.*, vol. 83, p. 392, 1934.



islands, other than Laurie Island, was made by the *Discovery II* Expedition in January, 1933.

According to Pirie,<sup>4</sup> these islands are composed entirely of ancient sedimentary rocks, chiefly greywackes and conglomerates. He states<sup>5</sup>

TABLE I. MINERALOGICAL COMPOSITION OF SOME ROCKS FROM THE  
SOUTH ORKNEY ISLANDS

Mineral	Specimen								
	1	2	6	4	9	5	7	8	3
Quartz	p	p	p	p	p	p	p	p	—
Orthoclase	p	p	p	p	p	p	p	—	—
Microcline	—	—	—	p	—	—	—	—	—
Plagioclase	p	p	p	p	p	p	p	—	p
Biotite	p	p	p	p	p	p	p	—	—
Pennine	p	p	p	p	p	p	p	p	p
Muscovite	p	p	p	p	p	p	p	—	—
Hornblende	—	p	p	p	—	p	p	—	—
Garnet	p	—	—	p	p	p	—	—	—
Apatite	p	p	p	p	p	p	p	—	—
Zircon	p	p	p	p	p	p	p	—	—
Epidote	p	p	p	p	p	p	p	?	—
Sphene	p	p	p	p	p	p	p	—	—
Rutile	?	p	p	p	p	p	p	?	—
Magnetite	p	p	p	p	p	p	p	—	p
Ilmenite	p	p	p	p	p	p	p	—	—
Pyrite	p	p	—	p	p	p	—	p	p
Limonite	—	p	p	p	—	p	—	p	p
Calcite	—	—	—	p	p	p	p	p	p
Leucoxene	p	p	p	p	p	p	p	—	—
Kaolin	p	p	p	p	p	p	p	—	p
Sericite	p	p	p	p	p	p	p	p	—

p=present in thin section.

1. Quartzite. Laurie I.
2. Quartzite. Laurie I.
6. Quartzite. Scotia Bay, Laurie I.
4. Conglomerite. Coronation I.
9. Conglomerite. Pt. Thomson, Laurie I.
5. Conglomerite. Pt. Thomson, Laurie I.
7. Arkosic conglomerite. Cape Whitson, Laurie I.
8. Slate. Graptolite I.
3. Altered diabase?. Jessie Bay, Laurie I.

<sup>4</sup> Pirie, J. H. H., First Antarctic voyage of the "Scotia," V. Note on the geology of the South Orkneys: *Scot. Geogr. Mag.*, vol. 20, p. 130, 1904.

<sup>5</sup> Pirie, J. H. H., On the graptolite-bearing rocks of the South Orkneys, With a note by Dr. Peach on specimens from the South Orkneys: *Proc. Roy. Soc. Edinb.*, 1904-1905, vol. 25, pp. 463-465 1906.

that the Scottish Expedition collected rock specimens mainly on Laurie Island, although single landings were made on Saddle and Coronation Islands. Included in his paper are brief descriptions of the Laurie specimens, which he divides into greywacke, greywacke-slate, and greywacke showing gneissic banding and folding. Høltedahl<sup>6</sup> examined some of the specimens in Pirie's collection and noted that in several, considerable deformational effects such as crushing of the mineral and rock fragments were common.

Nine thin sections of rocks from the South Orkney Islands were examined. Of these seven came from Laurie Island and consist of three quartzites, two conglomerites, an arkosic conglomerite, and an altered diabase?. The one specimen from Coronation Island is a conglomerite, and the one from Graptolite Island, a slate. A few fragments of micrographic intergrowths were noted in one of the conglomerites from Laurie Island. Deformational effects, as described by Høltedahl, may be seen in the bent and faulted plagioclase twinning lamellae.

#### ANTARCTIC ARCHIPELAGO

##### GENERAL STATEMENT

Fifteen papers on the geological and paleontological results of the Swedish Expedition have been published.<sup>7</sup> Andersson<sup>8</sup> has written a résumé of the geology of the northern area of the Antarctic Archipelago. The petrography of many of the rocks collected has been discussed by Nordenskjöld.<sup>9</sup> Hennig<sup>10</sup> has contributed to the petrography of the rocks of Cockburn Island. Petrographical analyses of 25 specimens, of which 20 were analyzed chemically, have been recorded by Bodman.<sup>11</sup>

Nordenskjöld<sup>12</sup> divides the Antarctic Archipelago into "die Zone der Gebirgskette" and "die Ostliche Zone (Zone der Erguss- und Sedimentgesteine)." The topography of the mountain chain zone is that of a high, almost wholly ice-free land, the western coast being strongly indented by

<sup>6</sup> Høltedahl, Olaf, *op. cit.*, p. 99.

<sup>7</sup> Nordenskjöld, Otto, *Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901-1903: Geologie und Paläontologie*, Band 3, 765 pp., 1916.

<sup>8</sup> Andersson, J. G., On the geology of Graham Land: *Uppsala Univ., Geol. Inst. Bull.*, 1904-1905, vol. 7, pp. 19-71, 1906.

<sup>9</sup> Nordenskjöld, Otto, *Petrographische Untersuchungen aus dem westantarktischen Gebiete: Uppsala Univ., Geol. Inst. Bull.*, 1902-1903, vol. 6, pp. 234-246, 1905.

<sup>10</sup> Hennig, Anders, Le conglomérat pleistocène à Pecten de l'île Cockburn, *Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901-1903: Geologie und Paläontologie*, Band 3, Lief. 10, pp. 6-9, 1916.

<sup>11</sup> Bodman, Gösta, *Petrographische Studien über einige antarktische Gesteine*, *Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901-1903: Geologie und Paläontologie*, Band 3, Lief. 15, pp. 1-100, 1916.

<sup>12</sup> Nordenskjöld, Otto, *op. cit.*, p. 235.

fjords. A number of expeditions have visited the islands of the western coast, outstanding among which have been those of Arctowski and Charcot. The petrography of the rocks collected by the Expédition Antarctique Belge has been recorded by Pelikan<sup>13</sup> and Sistek.<sup>14</sup> The petrographical results of the two Expéditions Antarctique Française have been monographed by Gourdon.<sup>15</sup> Intrusives are the principal rocks of the islands of the western area of the Antarctic Archipelago. The islands of the eastern zone are plateau-like with coast lines formed by vertical cliffs (as James Ross Island), composed of tuffs and basalts, with an elevation of approximately 2,000 meters, and low-lying islands, made up mainly of soft sedimentary rocks (Seymour Island), whose elevations above sea level are in the neighborhood of 200 meters.

The specimens examined came from the northern area of the Archipelago—Cockburn, Snow Hill, Seymour, James Ross, and Red Islands, and Hope Bay, Louis Philippe Land.

#### COCKBURN ISLAND

Cockburn Island is located in approximately Latitude 64°13' South, Longitude 56°50' West. Fossiliferous Cretaceous strata (Snow Hill series), intruded by basalt dikes, outcrop here and there through the talus that covers the steep sides of the island. Overlying these beds are basalts alternating with basic tuffs, upon which rests a localized deposit of post-Miocene Pecten-conglomerate. This conglomerate contains numerous blocks of basalt and basaltic tuff, many of which are of considerable dimensions, and a few pebbles of foreign crystalline rocks.

Thin sections of the following Cockburn rocks were examined: Glauconitic calcareous sandstone (Snow Hill series) from the northeastern part of the island; basic tuff, basalt, and olivine basalt from the steep sides of the island; vesicular and olivine basalts from the summit; olivine basalt dike intruding the Snow Hill series; basic tuff (Pecten-conglomerate formation); and a quartzite erratic.

Fragments of rocks and a piece of micrographic intergrowth are present in the sandstone. Basaltic glass, noted in some of the basic rocks, has an average index of refraction of 1.590.

<sup>13</sup> Pelikan, A., *Geologie, Petrographische Untersuchung der Gesteinsproben, Expédition Antarctique Belge, Résultats du Voyage du S. Y. Belgica en 1897-1898-1899: Rapports Scientifiques, Teil 1*, 49 pp., 1909.

<sup>14</sup> Sistek, Dragomir, *Geologie, Petrographische Untersuchung der Gesteinsproben, Expédition Antarctique Belge, Résultats du Voyage du S. Y. Belgica en 1897-1898-1899: Rapports Scientifiques, Teil 2*, 29 pp., 1912.

<sup>15</sup> Gourdon, E., *Géographie physique, glaciologie, pétrographie, Charcot, Expédition Antarctique Française 1903-05, Troisième partie*, pp. 141-208, 1908. *Minéralogie-géologie, Deuxième Expédition Antarctique Française 1908-10*, 10 pp., 1917.



## SNOW HILL ISLAND

Snow Hill Island, which is built up chiefly of gently dipping fossiliferous Cretaceous fine-grained, soft sandstones, is located approximately in Latitude  $64^{\circ}27'$  South, Longitude  $57^{\circ}15'$  West. A large basalt dike and numerous other smaller basic ones intrude these strata. Concretions of harder sandstone, more or less rich in glauconite, occur in the beds. The Snow Hill series is stratigraphically below the Older Seymour beds.

Thirty-seven sections of Snow Hill rocks were examined. The specimens were practically all gathered in the vicinity of the winter station, about in Latitude  $64^{\circ}22'$  South, Longitude  $57^{\circ}$  West, in the northern part of the island. The collection is made up of 14 specimens of limestones, including one erratic, four of which contain over one per cent glauconite, nine being arenaceous; six sandstones, three of which contain over one per cent glauconite; an arenaceous shale erratic; one diorite; an olivine basalt; four antigorite basalts, one of which is an erratic; an olivine analcite; one antigorite analcite; a quartz schist; five quartzites, including one erratic; and two marbles.

Chert, quartzite, diabase?, and other rock fragments occur in 13 sections, and pieces of micrographic intergrowths are noted in six sections of the sedimentary rocks. The igneous rocks, with one exception, exhibit zoned plagioclase feldspars.

## SEYMOUR ISLAND

Seymour Island is located in about Latitude  $64^{\circ}17'$  South, Longitude  $56^{\circ}47'$  West. Seymour may be divided into two parts on the basis of the ages of the sedimentary rocks. In the southwestern area are marine fossiliferous Cretaceous (Older Seymour Island) beds, cut by a large basalt dike, a probable continuation of the Snow Hill basalt; the northeastern part consists of fossiliferous marine upper Oligocene or lower Miocene (Younger Seymour Island) beds. The Tertiary rocks are sandstones, as are also the Cretaceous beds, cemented by calcite, and tuff containing fragments of augite porphyrite.

Nineteen of the 23 slides of Seymour Island rocks are of erratics—half of them having been collected from the northern area, and half from the southwestern part. The erratics include examples of all three classes of rocks. Two specimens of limestones were examined occurring in situ in the "Tvärdalen," and sections of quartzite and rhyolite, likewise occurring in situ on the island, were analyzed petrographically.

Prominent zoning of the plagioclase was noted in four of the nine sections of igneous rocks. Micrographic intergrowths occurred in four of the igneous specimens, and as a fragment in one of the limestones. Chert, quartzite, diabase, basalt, basic glass, shale, and schist fragments were recorded in four of the seven thin sections of sedimentary rocks.

## JAMES ROSS ISLAND

James Ross Island is a relatively large island whose central portion is in approximately Latitude  $64^{\circ}9'$  South, Longitude  $57^{\circ}30'$  West. It is built up almost exclusively of basalt tuff, which rests upon Cretaceous (Snow Hill series) beds.

The specimens examined were collected mainly in the vicinity of Cape Hamilton, in the southeastern part of the island. The seven thin sections studied include granodiorite, diabasic olivine gabbro (erratic), olivine basalt, basic tuff, limonitic limestone, and mica schist.

The plagioclase of the granodiorite and gabbro is zoned. Micrographic intergrowths are present in the granodiorite. The limestone contains fragments of quartzite and basic glass.

## HOPE BAY, LOUIS PHILIPPE LAND

Hope Bay is located in approximately Latitude  $63^{\circ}15'$  South, Longitude  $56^{\circ}50'$  West. Jurassic plant-bearing strata, the oldest known sedimentary rocks in the northern region of the Antarctic Archipelago, are exposed here. The plant remains are in a hard, dark, slaty rock which forms the lower part of Mount Flora, to the south of Hope Bay. A series of volcanic tuffs occur above the fossiliferous beds. Between the time of the deposition of the Older and Younger Seymour Island beds orogenic movements took place in the Archipelago and the plant-bearing series was involved in the folding, Nordenskjöld<sup>16</sup> remarks that the whole ice-free area north of Mount Flora is built up of sedimentary rocks, the principal type being greywacke, associated with a black slaty rock and light-colored, crossbedded sandstones. The underlying bedded rocks are conglomerates oftentimes containing good-sized boulders. Aside from the sedimentary rocks there is an important series of granite-diorite-gabbro eruptives.

Twenty-eight thin sections of rocks from the Hope Bay area were examined. Fifteen, including three erratics, are conglomerites and arkosic conglomerites, nine being from Mount Flora. In the collection there are examples of gabbro, trachyte, and quartz basalt erratics. Other rocks, collected in situ, include granite, gabbro, basalt, quartzite, arkosite, slate, and shale. Specimens of chert and schorlite were also examined.

Zoning of the plagioclase feldspars was noted in five of the seven sections of igneous rocks. Fragments of micrographic intergrowths are present in six of the metamorphosed sedimentaries. Limestone, chert, shale or slate, basic glass, basalt?, diabase?, and a micaceous rock occur as fragments in the metamorphic specimens. Bent and faulted plagi-

<sup>16</sup> Nordenskjöld, Otto, *op. cit.*, p. 239.

clase twinning lamellae are prominent features in ten sections of the conglomerites.

#### THE AGE OF THE INTRUSIVES

Referring to the age of the intrusive rocks Andersson<sup>17</sup> remarks that the age of the eruptives cannot be settled by means of field observations, but that it is probable, though not actually proved, that they are younger than the Jurassic beds of Hope Bay, as no fragments of the intrusive rocks were found in the conglomerates and tuffs of the Jurassic series. On the other hand no intrusions or metamorphic effects were noticed although they lie very close to one another. There is a considerable similarity between the intrusive rocks of the Patagonian Cordilleras of South America and those of the Archipelago, and judging from the probable age of the Andine eruptives, young Cretaceous or older Tertiary, Andersson considers it possible that those of the Antarctic Archipelago are of the same age. According to Nordenskjöld,<sup>18</sup> the plagioclase feldspars of the intrusives of the Hope Bay area exhibit zoning, and at times micropegmatitic intergrowths of orthoclase and quartz. These two features are apparently rather characteristic of the series.

As recorded above, micrographic intergrowths are present in five of the intrusives examined, and occur as fragments in 14 sedimentary and metamorphosed sedimentary rocks, which suggests that the sedimentary materials were derived from some of the intrusives of the granite-diorite-gabbro series. Taking into consideration the petrographical characteristics of the rocks of the northern region of the Archipelago, it is here suggested that some of the intrusives, at least, are older than the Jurassic sedimentary series of the Hope Bay area, and that the sediments were derived, in part, from the granite-diorite-gabbro series.

#### SUMMARY

A study was made of 114 thin sections of duplicate specimens collected by the Scottish National Antarctic, 1902-1904, and the Swedish Antarctic, 1901-1903, expeditions. The Scottish collections were gathered from the South Orkney Islands, and the Swedish from Cockburn, Snow Hill, Seymour, James Ross, and Red Islands, and Hope Bay, Louis Philippe Land, Antarctic Archipelago. It is suggested that the series of granite-diorite-gabbro eruptives of the northern region of the Archipelago were the source of, at least, some of the sediments of the Jurassic strata of the area, and, therefore, of greater age than that previously suggested—late Cretaceous or early Tertiary.

<sup>17</sup> Andersson, J. G., *op. cit.*, pp. 59-60.

<sup>18</sup> Nordenskjöld, Otto, *op. cit.* p. 237.



TABLE II. MINERALOGICAL COMPOSITION OF SOME IGNEOUS ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen								
	200289	200260	200376	200319	200329	200388	200199	200345	200373
Glass	—	—	—	—	—	—	—	—	—
Quartz	35.97	p	30.46	19.41	26.78	10.57	—	1.11	3.44
Feldspar	—	—	—	—	—	—	—	—	—
Orthoclase	28.39	p	30.84	8.92	15.08	7.11	—	—	—
Microcline	—	—	—	—	—	—	—	—	—
Microperthite	—	—	—	—	—	—	—	—	—
Plagioclase	—	—	—	—	—	—	63.39	—	—
Albite	—	—	—	—	—	—	p	—	—
Oligoclase	27.62	p	—	54.46	—	—	—	—	—
Andesine	—	—	30.11	—	51.49	66.28	p	—	—
Labradorite	—	—	—	—	—	—	—	69.60	61.49
Bytownite	—	—	—	—	—	—	—	—	—
Pennine	—	—	3.90	—	—	—	2.99	—	p
Biotite	0.96	p	—	7.51	4.72	11.89	—	6.86	p
Chlorite	—	p	—	—	—	—	—	—	p
Hornblende	—	—	3.23	7.55	p	—	26.43	18.04	10.73
Augite	—	—	—	—	—	—	—	—	15.31
Olivine	—	—	—	—	—	—	—	—	—
Antigorite	—	—	—	—	—	—	—	—	—
Chrysotile	—	—	—	—	—	—	—	—	—
Talc	—	—	—	—	—	—	—	—	—
Sphene	—	p	—	—	—	—	—	—	—
Tourmaline	?	?	—	—	?	?	abs	—	—
Apatite	p	p	0.43	0.21	—	2.28*	0.26	0.57	0.37
Zircon	p	p	—	—	—	—	abs	p	p
Muscovite	6.73	p	—	—	0.81	abs	—	p	4.41
Epidote	—	—	—	—	—	—	6.35	—	—
Zoisite	—	—	—	—	—	—	—	—	—
Garnet	0.34	—	—	—	—	—	—	—	—
Clinzoisite	—	—	—	—	—	—	—	—	—
Zeolite	—	—	—	—	—	—	—	—	—
Stilbite	—	—	—	—	—	—	—	—	—
Analcime	—	—	—	—	—	—	—	—	—
Tridymite	—	—	—	—	—	—	—	—	—
Chalcedony	—	—	—	—	—	—	—	—	—
Pyrite	—	—	—	—	—	—	—	3.83	—
Magnetite	p	p	1.03	1.93	1.12	1.87	0.58	—	1.29
Ilmenite	—	p	—	—	—	—	—	—	—
Hematite	—	—	—	—	—	—	—	—	—
Limonite	p	—	—	p	p	—	p	—	—
Calcite	—	p	—	—	—	—	—	p	p
Dolomite	—	—	—	—	—	—	—	—	—
Leucoxene	—	p	p	—	—	p	p	—	—
Kaolin	p	p	p	—	p	p	p	—	—
Sericite	p	p	p	p	p	p	p	p	p
	100.01	—	100.00	99.99	100.00	100.00	100.00	100.01	100.00

\* Mainly sphene and apatite. p = present in thin section.

200289. Leucogranite. Erratic. Seymour I.

200260. Biotite granite. Erratic. Seymour I.

200376. Granite. Hope Bay, Louis Philippe Land.

200319. Granodiorite. Erratic. Seymour I.

200329. Granodiorite. Erratic. Seymour I.

200388. Granodiorite. James Ross I.

200199. Diorite. Snow Hill I.

200345. Gabbro. Erratic. Hope Bay, Louis Philippe Land.

200373. Gabbro. Hope Bay, Louis Philippe Land.

TABLE II. MINERALOGICAL COMPOSITION OF SOME IGNEOUS ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen								
	200402	200258	200336	200273	200267	200324	200344	200351	16563
Glass.....	—	—	—	—	—	—	—	—	p
Quartz.....	—	p	p	p	p	p	—	p	p
Feldspar.....	—	—	p	—	—	—	—	—	—
Orthoclase.....	—	p	—	p	p	p	p	—	—
Microcline.....	—	—	—	—	—	—	—	—	—
Microperthite.....	—	p	—	p	p	—	—	—	—
Plagioclase.....	—	—	—	p	—	p	p	—	—
Albite.....	—	p	—	—	p	—	—	—	—
Oligoclase.....	—	—	—	—	—	—	—	—	—
Andesine.....	—	—	—	—	—	—	—	—	—
Labradorite.....	—	—	—	—	—	—	—	p	p
Bytownite.....	58.45	—	—	—	—	—	—	—	—
Pennine.....	—	p	—	p	—	—	p	—	—
Biotite.....	—	p	p	p	p	—	p	—	—
Chlorite.....	—	p	p	p	p	—	—	p	—
Hornblende.....	—	—	—	—	—	—	p	p	—
Augite.....	15.39	—	—	—	—	—	—	p	—
Olivine.....	21.94	—	—	—	—	—	—	—	p
Antigorite.....	—	—	—	—	—	—	—	—	p
Chrysotile.....	—	—	—	—	—	—	—	—	—
Talc.....	—	—	—	—	—	—	—	—	—
Sphene.....	—	p	—	p	p	—	p	p	—
Tourmaline.....	—	—	—	—	—	—	—	—	—
Apatite.....	p	p	p	p	p	—	p	p	—
Zircon.....	—	p	p	—	—	—	—	—	—
Muscovite.....	—	p	p	—	p	—	p	—	—
Epidote.....	—	p	—	p	—	—	p	—	—
Zoisite.....	—	—	—	—	—	—	—	—	—
Garnet.....	—	—	—	—	—	—	—	—	—
Clinozoisite.....	—	—	p	—	—	—	—	—	—
Zeolite.....	—	—	—	—	—	—	—	—	—
Stilbite.....	—	—	—	—	—	—	—	—	—
Analcime.....	—	—	—	—	—	—	—	—	—
Tridymite.....	—	—	—	—	—	—	—	—	—
Chalcedony.....	—	—	—	—	—	—	—	—	—
Pyrite.....	—	p	—	—	—	—	p	p	—
Magnetite.....	4.21	—	p	p	—	p	p	p	—
Ilmenite.....	—	—	—	—	p	—	—	—	—
Hematite.....	—	—	—	p	—	—	—	—	—
Limonite.....	p	p	—	p	p	—	p	—	p
Calcite.....	—	p	—	—	p	—	p	p	p
Dolomite.....	—	—	—	—	—	—	—	—	—
Leucoxene.....	—	p	—	—	p	—	p	—	—
Kaolin.....	—	p	p	p	p	—	p	—	—
Sericite.....	—	p	p	—	p	—	p	—	—
	99.99	—	—	—	—	—	—	—	—

p = present in thin section.

200402. Diabasic olivine gabbro. Erratic. James Ross I.

200258. Granophyre. Erratic. Seymour I.

200336. Granophyre. Erratic. Seymour I.

200273. Pegmatophyre. Erratic. Seymour I.

200267. Rhyolite. Seymour I.

200324. Rhyolite. Erratic. Seymour I.

200344. Trachyte. Erratic. Hope Bay, Louis Philippe Land.

200351. Quartz basalt. Erratic. Hope Bay, Louis Philippe Land.

16563. Basalt. Cockburn I.

TABLE II. MINERALOGICAL COMPOSITION OF SOME IGNEOUS ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen								
	16564	200370	200374	16565	16567	16568	200203	200390	200205
Glass.....	p	—	—	—	—	p	—	p	—
Quartz.....	—	—	—	—	—	—	—	—	—
Feldspar.....	—	—	—	—	—	—	—	—	—
Orthoclase.....	—	—	—	—	—	—	—	—	—
Microcline.....	—	—	—	—	—	—	—	—	—
Microperthite.....	—	—	—	—	—	—	—	—	—
Plagioclase.....	—	—	—	—	—	—	—	—	—
Albite.....	—	—	—	—	—	—	—	—	—
Oligoclase.....	—	—	—	—	—	—	—	—	—
Andesine.....	—	—	—	p	—	—	—	—	—
Labradorite.....	—	p	p	—	p	54.62	p	p	p
Bytownite.....	p	—	—	—	—	—	—	—	—
Pennine.....	—	—	—	—	—	—	—	—	—
Biotite.....	—	p	p	—	—	—	—	—	—
Chlorite.....	—	—	p	—	—	—	?	p	—
Hornblende.....	—	—	—	—	—	—	—	—	—
Augite.....	—	p	p	—	p	14.96	p	—	—
Olivine.....	p	—	—	p	p	3.55	p	p	—
Antigorite.....	—	—	—	p	—	p	p	—	p
Chrysotile.....	—	—	—	p	—	—	—	p	—
Talc.....	—	—	—	—	—	—	—	—	—
Sphene.....	—	—	—	—	—	—	—	—	—
Tourmaline.....	p	—	—	—	—	—	—	—	—
Apatite.....	—	—	p	—	p	—	p	—	—
Zircon.....	—	—	—	—	—	—	—	—	—
Muscovite.....	—	—	—	—	—	—	—	—	—
Epidote.....	—	—	—	—	—	—	—	—	—
Zoisite.....	—	—	—	—	—	—	—	—	—
Garnet.....	—	—	—	—	—	—	—	—	—
Clinzoisite.....	—	—	—	—	—	—	—	—	—
Zeolite.....	—	—	—	—	—	—	—	p	—
Stilbite.....	—	—	?	—	—	—	—	—	—
Analcime.....	—	—	—	—	—	2.87	—	—	—
Tridymite.....	—	—	—	—	—	—	—	—	—
Chalcedony.....	—	—	—	—	—	—	—	—	—
Pyrite.....	—	—	—	—	—	—	—	—	p
Magnetite.....	p	p	p	—	p	3.26	p	p	p
Ilmenite.....	—	—	—	—	—	—	—	—	—
Hematite.....	—	—	—	p	p	—	—	—	p
Limonite.....	p	p	p	p	—	p	p	p	p
Calcite.....	p	p	—	p	p	20.74	p	p	—
Dolomite.....	—	—	—	—	—	—	—	—	p
Leucoxene.....	—	—	—	—	—	—	—	—	—
Kaolin.....	—	—	—	—	—	—	—	—	—
Sericite.....	—	—	—	—	—	—	p	—	—
	—	—	—	—	—	100.00	—	—	—

p = present in thin section.

16564. Basalt. Cockburn I.

200370. Basalt. Hope Bay, Louis Philippe Land.

200374. Basalt. Hope Bay, Louis Philippe Land.

16565. Vesicular basalt. Cockburn I.

16567. Olivine basalt. Cockburn I.

16568. Olivine basalt. Cockburn I.

200203. Olivine basalt. Snow Hill I.

200390. Olivine basalt. James Ross I.

200205. Antigorite basalt. Snow Hill I.



TABLE II. MINERALOGICAL COMPOSITION OF SOME IGNEOUS ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen								
	200215	200222	200247	200221	200243	16561	200411	200389	200408
Glass.....	—	p	—	—	—	p	p	p	p
Quartz.....	—	p	p	—	p	p	p	p	p
Feldspar.....	—	—	—	—	—	—	—	—	—
Orthoclase.....	—	—	—	—	—	—	—	—	—
Microcline.....	—	—	—	—	—	—	—	—	—
Microperthite.....	—	—	—	—	—	—	—	—	—
Plagioclase.....	—	—	—	—	—	—	—	p	—
Albite.....	—	—	—	—	—	—	—	—	—
Oligoclase.....	—	—	—	—	—	—	—	—	—
Andesine.....	—	—	—	—	—	—	—	—	—
Labradorite.....	—	p	p	p	p	—	p	—	p
Bytownite.....	p	—	—	—	—	p	—	—	—
Pennine.....	—	—	—	—	—	—	—	—	—
Biotite.....	—	—	—	—	—	—	—	—	—
Chlorite.....	—	—	—	—	—	p	p	p	p
Hornblende.....	—	—	—	—	—	—	—	—	—
Augite.....	p	—	—	p	—	p	p	—	—
Olivine.....	—	—	—	p	p	p	p	p	p
Antigorite.....	p	p	p	p	p	p	—	—	—
Chrysotile.....	p	—	—	—	p	—	—	—	p
Talc.....	—	—	—	—	—	p	—	—	p
Sphene.....	p	—	—	—	—	—	—	—	—
Tourmaline.....	—	—	—	—	—	—	p	—	—
Apatite.....	—	—	—	—	—	—	—	—	—
Zircon.....	—	—	—	—	—	—	—	—	—
Muscovite.....	—	—	—	—	—	—	—	—	—
Epidote.....	—	—	—	—	—	—	—	—	—
Zoisite.....	—	—	—	—	—	—	—	—	—
Garnet.....	—	—	—	—	—	—	—	—	—
Clinzoisite.....	—	—	—	—	—	—	—	—	—
Zeolite.....	—	—	—	—	—	—	—	—	—
Stilbite.....	—	—	—	—	—	—	—	—	?
Analcime.....	—	—	p	p	p	—	—	p	—
Tridymite.....	—	—	—	—	—	?	—	—	—
Chalcedony.....	—	—	—	—	—	—	—	?	—
Pyrite.....	—	p	—	—	—	p	—	—	—
Magnetite.....	—	p	p	p	p	p	p	p	p
Ilmenite.....	p	p	—	—	—	—	—	—	—
Hematite.....	—	p	p	p	p	—	p	—	—
Limonite.....	p	p	p	p	p	p	p	p	p
Calcite.....	p	p	p	p	p	p	p	p	—
Dolomite.....	—	—	—	—	—	—	—	—	—
Leucoxene.....	p	—	p	—	p	—	—	—	—
Kaolin.....	—	—	—	—	—	—	p	—	—
Sericite.....	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—

p = present in thin section.

200215. Antigorite basalt. Snow Hill I.

200222. Antigorite basalt. Snow Hill I.

200247. Antigorite basalt. Snow Hill I.

200221. Olivine analcite. Snow Hill I.

200243. Antigorite analcite. Snow Hill I.

16561. Basic tuff. Cockburn I.

200411. Basic tuff. Cockburn I.

200389. Basic tuff. James Ross I.

200408. Basic tuff. James Ross I.

TABLE III. MINERALOGICAL COMPOSITION OF SEDIMENTARY ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen														
	200256	200291	200386	200248	200177	200220	200226	200242	200308	200179	200211	200228	200241	200244	200311
Quartz.....	p	p	p	p	—	—	p	—	p	p	p	p	30.44	p	11.78
Microcline.....	—	—	—	—	—	—	—	—	—	—	—	—	—	p	—
Orthoclase.....	—	—	—	—	—	—	—	—	—	—	—	—	—	p	—
Plagioclase.....	—	p	p	p	—	—	p	—	—	p	p	p	14.42	p	3.29
Enstatite.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?
Augite.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hornblende.....	—	—	—	—	—	—	—	—	p	p	p	p	0.36	p	0.32
Glaucophane.....	p	—	p	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorite.....	p	—	p	p	—	—	—	—	p	p	p	p	—	p	—
Apatite.....	p	—	p	p	—	—	—	—	p	p	p	p	—	p	—
Biotite.....	p	—	p	p	—	—	—	—	p	p	p	p	—	p	—
Muscovite.....	p	p	p	—	—	—	—	—	p	p	p	p	—	p	—
Garnet.....	p	p	p	p	—	—	p	—	p	p	p	p	1.76	p	0.74
Zircon.....	—	—	—	—	—	—	p	—	p	p	p	p	—	p	—
Rutile.....	p	—	p	p	—	—	p	—	p	p	p	p	—	p	—
Magnetite.....	p	p	p	—	—	—	p	p	p	p	p	p	—	p	—
Limonite.....	p	p	—	—	—	—	p	—	p	p	p	p	—	p	—
Ilmenite.....	p	p	—	—	—	—	—	—	p	p	p	p	—	p	—
Leucoxene.....	p	p	—	—	—	—	—	—	p	p	p	p	—	p	—
Sphene.....	p	p	—	—	—	—	p	—	p	p	p	p	—	p	—
Pyrite.....	p	p	—	—	—	—	—	—	p	p	p	p	—	p	—
Epidote.....	p	p	—	—	—	—	—	—	p	p	p	p	—	p	—
Zeolite.....	—	—	—	—	—	p	p	p	p	p	p	p	53.01	p	83.88
Calcite.....	—	p	—	p	p	—	—	—	p	p	p	p	—	p	—
Penine.....	p	p	—	—	—	—	—	—	—	—	—	—	—	—	—
Clinzoisite.....	p	p	—	—	—	—	—	—	—	—	—	—	—	—	—
Hematite.....	p	p	—	—	—	—	—	—	—	p	p	p	p	p	p
Kaolin.....	p	p	—	p	—	—	—	—	—	p	p	p	p	p	p
Sericite.....	—	—	—	—	—	—	—	—	—	—	—	—	99.99	—	100.01

p = present in thin section.

200241: Arenaceous limestone. Snow Hill I.

200228: Arenaceous limestone. Snow Hill I.

200244: Arenaceous limestone. Snow Hill I.

200244: Arenaceous limestone. Erratic. Snow Hill I.

200311: Arenaceous limestone. Erratic. Seymour I.

200220: Limestone. Snow Hill I.

200226: Limestone. Snow Hill I.

200242: Limestone. Snow Hill I.

200308: Limestone. Seymour I.

200179: Arenaceous limestone. Snow Hill I.

\* Mainly glass and rock fragments.

200256: Shale. Erratic. Seymour I.

200291: Shale. Erratic. Seymour I.

200386: Shale. Hope Bay, Louis Philippe Land.

200248: Arenaceous shale. Erratic. Snow Hill I.

200177: Limestone. Snow Hill I.

TABLE III. MINERALOGICAL COMPOSITION OF SOME SEDIMENTARY ROCKS FROM THE NORTHEASTERN AREA OF THE NORTHERN ARCHPELAGO

Mineral	Specimen																			
	200189	200708	200236	200240	200406	200209	200312	200207	16560	200182	200235	200192	200229	200181	200287					
Quartz.....	24.26	17.97	17.76	p	p	p	1.92	p	36.36	p	p	p	p	16.52	p					
Microcline.....	13.43	9.58	8.78	p	p	p	4.95	p	5.07	p	p	p	p	{ 15.69	p					
Orthoclase.....				p	p	p		p		p	p	p								
Plagioclase.....	—	—	—	p	p	p	?	—	—	—	—	—	—	—	p					
Eustatite.....	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—					
Augite.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					
Hornblende.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					
Glaucinite.....	3.57	1.41	2.07	p	p	p	abs	p	4.68	p	p	p	p	23.52	—					
Tourmaline.....	—	abs	—	—	—	—	—	—	—	p	p	p	p	—	p					
Chlorite.....	—		p	p	p	—	—	—	—	p	p	p	p	—	p					
Apatite.....	—		—	—	—	—	—	—	—	—	p	p	p	p	p	p				
Biotite.....	—		—	—	—	—	—	—	—	—	p	p	p	p	p	p				
Muscovite.....	—	—	—	p	p	p	—	p	—	p	p	p	p	—	p					
Garnet.....	1.06	1.36	3.62	p	p	p	14.91*	p	5.72	p	p	p	p	{ 2.39	p					
Zircon.....				—	—	—		—		—	—	—	—		—	—	—			
Rutile.....				p	p	p		p		p	p	p	p		p	p	p	p	p	p
Magnetite.....				p	p	p		p		p	p	p	p		p	p	p	p	p	p
Limonite.....	—	—	—	p	p	p	—	p	—	p	p	p	p	abs	p					
Ilmenite.....	—	—	—	p	p	p	abs	p	—	p	p	p	p		p	p				
Leucoxene.....	—	—	—	p	p	p	abs	p	—	p	p	p	p		p	p				
Sphene.....	—	—	—	p	p	p	abs	p	—	p	p	p	p		p	p				
Pyrite.....	—	—	—	—	—	—	—	—	—	p	—	—	—	—	—					
Epidote.....	—	—	—	p	p	p	—	—	—	—	—	—	—	—	—					
Zeolite.....	—	—	—	—	—	—	—	—	—	—	—	—	p	{ 41.19	p					
Calcite.....	57.68	69.68	67.78	p	p	p	78.22	—	48.17	p	p	p	p		p	p				
Pennine.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					
Clinzoisite.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					
Hematite.....	p	p	p	p	p	p	p	p	p	p	p	p	—	p	p					
Kaolin.....	p	p	p	p	p	p	—	p	p	p	p	p	—	p	p					
Sericite.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—					

\* Mainly glass and rock fragments.

200189. Glauconitic arenaceous limestone. Snow Hill I.  
 200208. Glauconitic arenaceous limestone. Snow Hill I.  
 200236. Glauconitic arenaceous limestone. Snow Hill I.  
 200240. Glauconitic arenaceous limestone. Snow Hill I.  
 200406. Limonitic limestone. James Koss I.

200209. Limonitic arenaceous limestone. Snow Hill I.  
 200312. Impure limestone. Seymour I.  
 200207. Calcareous sandstone. Snow Hill I.  
 16560. Glauconitic calcareous sandstone. Cockburn I.  
 200182. Glauconitic limonitic sandstone. Snow Hill I.

p = present in thin section.

200235. Glauconitic limonitic sandstone. Snow Hill I.  
 200192. Limonitic sandstone. Snow Hill I.  
 200229. Limonitic sandstone. Snow Hill I.  
 200181. Glauconitic calcareous arkose. Snow Hill I.  
 200287. Conglomerate. Erratic. Seymour I.



TABLE IV. MINERALOGICAL COMPOSITION OF SOME METAMORPHIC ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen																		
	200202	200223	200231	200232	200301	200334	200380	200414	200206	200362	200186	200259	200274	200293	200393	200285	200363	200423	200227
Quartz.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Feldspar.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Orthoclase.....																			
Microcline.....																			
Microperthite.....																			
Plagioclase.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Biotite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Chlorite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Pennine.....																			
Hornblende.....																			
Actinolite.....																			
Dioctahedral.....																			
Muscovite.....	p						p	p			p	p	p	p	p	p	p	p	p
Rutile.....																			
Tourmaline.....																			
Garnet.....							p												
Corundum.....																			
Apatite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Zircon.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Epidote.....																			
Clinozoisite.....																			
Spinel.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Magnetite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Ilmenite.....																			
Pyrite.....																			
Hematite.....																			
Limonite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Calcite.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Leucocene.....	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Kaolin.....																			
Sericite.....																			

p = present in thin sections.

200202. Quartzite. Snow Hill I.  
 200223. Quartzite. Snow Hill I.  
 200231. Quartzite. Snow Hill I.  
 200232. Quartzite. Snow Hill I.  
 200301. Quartzite. Seymour I.  
 200334. Quartzite. Seymour I.  
 200380. Quartzite. Hope Bay, Louis Philippe Land.  
 200414. Quartzite. Erratic. Cockburn I.  
 200206. Calcareous quartzite. Erratic. Snow Hill I.  
 200362. Arkosite. Hope Bay, Louis Philippe Land.

200186. Quartz schist. Snow Hill I.  
 200259. Quartz schist. Erratic. Seymour I.  
 200274. Quartz schist. Erratic. Seymour I.  
 200293. Micaceous quartz schist. Erratic. Seymour I.  
 200393. Mica schist. James Ross I.  
 200285. Slate. Erratic. Seymour I.  
 200363. Slate. Hope Bay, Louis Philippe Land.  
 200423. Biotite gneiss. Erratic. Red I.  
 200227. Marble. Snow Hill I.

TABLE IV. MINERALOGICAL COMPOSITION OF SOME METAMORPHIC ROCKS FROM THE NORTHEASTERN AREA OF THE ANTARCTIC ARCHIPELAGO

Mineral	Specimen															
	200238	200275	200281	200343	200356	200357	200361	200365	200366	200372	200378	200381	200387	200368	020369	200379
Quartz	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Feldspar	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Orthoclase	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microcline	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microperthite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Plagioclase	—	p	—	p	p	p	p	p	p	p	p	p	p	p	p	p
Biotite	—	p	—	p	p	p	p	p	p	p	p	p	p	p	p	p
Chlorite	—	p	—	p	p	p	p	p	p	p	p	p	p	p	p	p
Fennite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hornblende	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Actinolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dioptase	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Muscovite	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Rutile	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garnet	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corundum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apatite	—	—	—	p	p	p	p	p	p	p	p	p	p	p	p	p
Zircon	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Epidote	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Clinzoisite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Spinel	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Magnetite	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Ilmenite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pyrite	p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hematite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Limonite	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Calcite	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Leucoxene	—	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Kaolin	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sericite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

p = present in thin section.

200238. Marble, Snow Hill I.  
 200275. Conglomerite, Erratic, Seymour I.  
 200281. Conglomerite, Erratic, Hope Bay, Louis Philippe Land.  
 200343. Conglomerite, Erratic, Hope Bay, Louis Philippe Land.  
 200356. Conglomerite, Erratic, Hope Bay, Louis Philippe Land.  
 200357. Conglomerite, Erratic, Hope Bay, Louis Philippe Land.  
 200361. Conglomerite, Hope Bay, Louis Philippe Land.  
 200365. Conglomerite, Hope Bay, Louis Philippe Land.  
 200366. Conglomerite, Hope Bay, Louis Philippe Land.  
 200372. Conglomerite, Hope Bay, Louis Philippe Land.  
 200378. Conglomerite, Erratic, Hope Bay, Louis Philippe Land.  
 200381. Conglomerite, Hope Bay, Louis Philippe Land.  
 200387. Conglomerite, Hope Bay, Louis Philippe Land.  
 200368. Arkosic conglomerite, Hope Bay, Louis Philippe Land.  
 200369. Arkosic conglomerite, Hope Bay, Louis Philippe Land.  
 200375. Arkosic conglomerite, Hope Bay, Louis Philippe Land.  
 200379. Arkosic conglomerite, Hope Bay, Louis Philippe Land.  
 200383. Arkosic conglomerite, Hope Bay, Louis Philippe Land.

## MEMORIAL OF ROY JED COLONY

PAUL F. KERR, *Columbia University, New York City.*

Roy Jed Colony, widely known and highly respected in the scientific field and in professional circles for many years, died in Bronxville, New York, March 25, 1936, at the age of sixty-six years.

Professor Colony was born in St. Louis, Missouri, March 5, 1870, the son of Myron and Josephine Colony. The early years of his life were spent in the western United States and in Mexico. His early education was in military schools, and a broad practical experience and training in mining problems were largely obtained in a number of important mining centers of the west.

At the age of thirty he entered Cooper Union and was graduated in chemistry in 1905. He became Assistant Professor of Chemistry at Cooper Union in 1906, and while there became interested in the application of petrography to engineering projects. His research in Portland cement for the New York City Board of Water Supply, for which he served as consulting engineer during 1915-1916, eventually led to his appointment in 1916 as Instructor of Geology at Columbia University. In 1922 he received the degree of Master of Arts in geology from Columbia University. He was made Assistant Professor in 1922, and Associate Professor in 1931.

At the time of his death, Professor Colony had attained an outstanding reputation in two important phases of the geological field. His genial personality, untiring patience, facility in explanation, and thorough knowledge of his subject gained for him the reputation of being one of the best teachers of petrography. He was a favorite among his students, and his advice was frequently sought, not only in connection with class work but with personal problems as well. His other great contribution was in the field of applied petrography. A carefully recorded file of his numerous petrographic studies, with accompanying suites of specimens, forms an important part of the petrographic collection of Columbia University.

Although it was well after the middle of his life when Professor Colony began work in the field in which he made his most important contribution, he engaged in an unusual number of projects of importance and general interest. In 1930 he prepared a report on the Geology of Saratoga Springs which was offered to the New York State Legislature by the Saratoga Springs Commission. In 1933 he prepared a report on the Geology of the Santee-Cooper project in South Carolina. He was an authority on the petrography of Portland cement and cooperated with





*Blackstone Studio*

ROY JED COLONY  
1870-1936

the Engineering Testing Laboratories in numerous problems involving the use of Portland cement. At the time of his death he was engaged in the revision of Kemp's *Handbook of Rocks*.

Consulting problems involving the application of geology to a wide variety of subjects were frequently referred to Professor Colony. The interpretation of the conditions of ore deposition from petrographic study, foundation deterioration problems in connection with large buildings on Manhattan Island, engineering geology, and studies of building stone were subjects upon which he was frequently consulted. His most recent work concerned the microscopic study of the minerals responsible for silicosis.

Professor Colony was active and highly regarded in scientific circles. He was elected a Fellow of the Mineralogical Society of America in December 1925 and was its official nominee for Vice-president at the time of his death. He was elected a Fellow of the Geological Society of America in December 1924. He was also a Fellow of the American Geographical Society. Professor Colony was active in the New York Academy of Sciences, being elected an associate member May 17, 1915, an active member November 7, 1921, and a Fellow December 19, 1921. He served as Chairman of the Division of Geology and Mineralogy, and Vice-president of the Academy in 1926-1927, and was a member of the Council for the term 1933-1935.

Professor Colony was active in the affairs of the American Institute of Mining and Metallurgical Engineers. He was a member of the American Association for the Advancement of Science, and his activity in applied geology was portrayed by membership in the Society of Economic Geologists.

The more prominent contributions of Professor Colony include the study of the magnetite iron deposits of southeastern New York, a report to the Saratoga Springs Commission on a re-study of the geology of the Saratoga area and the problem of the mineral waters, an investigation of the constitution of Portland cement and the properties of cement components with relations to disintegration of concrete, and the geology of the Schunemunk quadrangle. Unfortunately, one of his chief contributions, the geology of the Schunemunk quadrangle, was incomplete at the time of his death.

Professor Colony married Miss Lulu May Hoffman, of Laredo, Texas, on October 10, 1894. His widow, a son, Myron W. Colony, of California, two daughters, Mrs. Charles E. Fiero of Bronxville, New York, and Mrs. Ruth Sorelle, of Margaretville, New York, and nine grandchildren survive.

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# PROCEEDINGS OF THE SEVENTEENTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA AT CINCINNATI, OHIO

PAUL F. KERR, *Secretary*.

The seventeenth annual meeting of the Society was called to order Tuesday, December 29th, at 1:30 P.M., in the Pavillon Caprice of the Netherland Plaza Hotel, 5th and Race Streets, Cincinnati, Ohio, President William S. Bayley presiding. The customary business of the Society was conducted, including reports by the officers of the Society and committees summarized as follows:

## MINUTES OF THE LAST ANNUAL MEETING.

### REPORT OF THE SECRETARY.

### REPORT OF THE EDITOR.

### REPORT OF THE TREASURER.

### MEMORIAL:

A brief oral tribute was presented by Dean Edward H. Kraus of the University of Michigan, for Roy J. Colony, late Fellow of the Society.

### COMMITTEES:

#### REPORT OF THE AUDITING COMMITTEE.

The business meeting was adjourned at 2:00 P.M., and the president, William S. Bayley, called for the presentation of papers. The report of the election of officers and fellows for 1937, the reports of the Secretary, Editor, and Treasurer, and the reports of the committees are given in the following pages.

## ELECTION OF OFFICERS AND FELLOWS FOR 1937

The Secretary announced that 229 ballots have been cast unanimously for the officers as nominated by the Council. The officers for 1937 are as follows:

*President:* Norman L. Bowen, Geophysical Laboratory, Washington, D. C.

*Vice-President:* Hardy V. Ellsworth, Canada Geological Survey, Ottawa, Canada.

*Secretary:* Paul F. Kerr, Columbia University, New York, N. Y.

*Treasurer:* Waldemar T. Schaller, U. S. Geological Survey, Washington, D. C.

*Editor:* Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

*Councilor, 1937-1940:* Arthur P. Honess, State College, Pa.

The Secretary announced that according to the provisions of the Constitution, the following had been elected to Fellowship in the Mineralogical Society of America:

Charles A. Anderson, University of California, Berkeley, California.

Bert S. Butler, University of Arizona, Tucson, Arizona.

Burnham S. Colburn, Greystone Court, Biltmore, North Carolina.

Louis C. Graton, Harvard University, Cambridge, Massachusetts.

Albert Johannsen, University of Chicago, Chicago, Illinois.

Waldemar Lindgren, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Warren J. Mead, Massachusetts Institute of Technology, Cambridge, Massachusetts.  
Frederick K. Morris, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Gilman S. Stanton, 245 West 104 St., New York, N. Y.

Carl Tolman, Washington University, St. Louis, Missouri.

M. Vonsen, Petaluma, California.

Alfred O. Woodford, 443 West Tenth St., Claremont, California.

#### AMENDMENT TO CONSTITUTION

The Secretary announced that the following amendment to the constitution of the Mineralogical Society of America had been passed by a vote of the fellows:

"Outstanding scientists of recognized scientific accomplishments in the field of Mineralogy, Petrography, Crystallography, and allied sciences, who are members of other scientific societies in the field of geology, such as the Geological Society of America, Society of Economic Geologists, American Institute of Mining and Metallurgical Engineers, the American Association of Petroleum Geologists, and other similar scientific societies, may be nominated for FELLOWSHIP in the Society upon recommendation of the Council."

#### REPORT OF THE SECRETARY FOR 1936

*To the Council, Fellows and Members of the Mineralogical Society of America:*

The Secretary reports the statistics concerning the membership of the Society for the last twelve months as follows:

##### MEMBERSHIP STATISTICS

	<i>December 1935</i>	<i>December 1936</i>
Correspondents	4	4
Fellows	132	154
Members	336	387
Subscribers	281	305
	<hr/> 753	<hr/> 850

##### GAIN AND LOSS FOR 1936

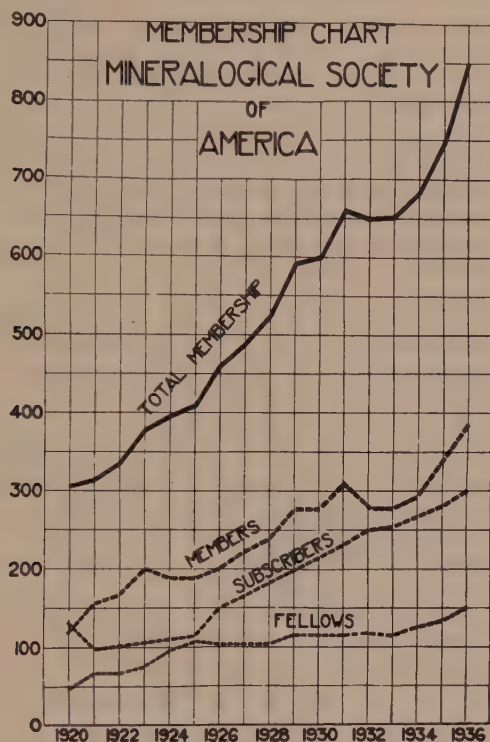
	<i>Gain</i>	<i>Loss</i>
Correspondents		
Fellows (not including members elected fellows)		1
Members	100	26
Subscribers	45	21
	<hr/> 145	<hr/> 48

During 1936 the Mineralogical Society of America has made a net gain in membership of 97, or slightly over 12% on the basis of the 1935 total. There has been a gain in both members and subscribers for the past year, and as last year, the greatest gain has been in the members.

About 850 copies of *The American Mineralogist* are sent out each month. The majority of these go to the United States and Canada, but more than 150 are sent to Europe, Asia, Africa and South America.

It has been the custom of the Secretary's office to record the membership status of the Society for each preceding year in the March issue of *The American Mineralogist*. The figures given apply to the last year and the year immediately preceding, but it has not been the custom to attempt any general review covering a period of years. It is felt that in such a report the significance of the figures, in relationship to the general progress of the Society may be overlooked.

In order to more effectively inform the membership of the progress of the Mineralogical Society of America, since it was first organized, a membership chart covering the entire life of the Society is included for 1936.



The membership chart emphasizes a number of features which should be of interest to all members of the Society. At the completion of the organization period in the latter part of 1919, and during 1920, the total membership of the Society amounted to 303. Since that time, with the exception of two years during the depression, the total membership of the Society has not failed to show an increase. It is also interesting to observe that the loss of members recorded during the depression has been made up and the growth curve of the Society at present appears to be following a normal trend, at least, and is perhaps a little higher than normal. From an original membership of 303, the Society has grown in the seventeen years of its activity to a total membership of 850.

Respectfully submitted,

PAUL F. KERR, *Secretary*

#### REPORT OF THE EDITOR FOR 1936

*To the Council, Fellows and Members of The Mineralogical Society of America:*

In many respects, from the Editor's standpoint, 1936 might be considered a very satisfactory year. The current volume contains 818 pages of text material and compares favorably with the volume of a year ago, which was the largest in the history of the Society.



While the volume of 1935 contains approximately 65 more pages, it should be recalled that the printed page of the current volume is somewhat larger than that used a year ago, so that the total volume of printed material for the past two years is approximately the same.

The enlarged volume of the Journal this past year, as in 1936, was due, in part, to some financial assistance received from the Geological Society of America, which is here gratefully acknowledged. The Council of the G.S.A. at a meeting held last October graciously voted to recommend the continuance of this assistance during 1937.

The Subject-Author Index covering the first twenty volumes of *The American Mineralogist*, which has been in preparation for some time, was completed during the year and distributed to those who had placed orders with the Treasurer. As the cost for the preparation and printing of this time-saving index was in excess of \$1100, the Council has deemed it necessary to place a nominal price of \$1.00 per copy, for members of the Society. So far the returns to the Society on this investment have been less than \$150. Orders can still be supplied from the surplus stock and the readers of the Journal are urged to secure copies while they are still available.

An analysis of volume 21 shows that 85% of the total space of the Journal was devoted to 62 major articles. This is the equivalent of more than 5 leading articles to an issue. While a number of these contributions represent fairly long papers, the great majority were of moderate length, so that the average for the entire number is 12 printed pages for each article. In addition to these main contributions, 29 somewhat shorter papers were accepted, making a total for the year of 91 published manuscripts that were received from 91 contributors. The service rendered by the Society's publication is clearly revealed by the 42 institutions that are represented by this year's contributions. These institutions are not confined to the States, as 9 papers (some of joint authorship) were received from countries beyond our own borders—2 from Soviet Russia, 3 from Belgium, and one each from Canada, Japan, England, and Holland.

While the papers offered the readers this year cover 8 special divisions, it will be noted that articles on descriptive mineralogy, chemical mineralogy, and petrography lead the list with at least 10 papers in each of these fields. Contributions to optical mineralogy, structural crystallography and geometrical crystallography were, however, almost as numerous.

To bring before our readers reviews of recent books that have appeared on mineralogy is an important function of the Journal and during the current year 13 such reviews have been prepared and printed.

Inasmuch as illustrations and photographs are aids to the understanding of technical papers, a very liberal policy has been followed in recent years in the number of cuts accepted. This number has grown steadily from year to year, and in 1936 reached the high level mark of 268.

The accompanying table of contents summarizes in detail the distribution of subject matter in volume 21.

## DISTRIBUTION OF SUBJECT MATTER IN VOLUME 21

<i>Subjects</i>	<i>Articles</i>	<i>Pages</i>	<i>Per Cent of Total</i>
Leading articles			
Descriptive mineralogy	13		
Chemical mineralogy	11		
Optical mineralogy	5		
Mineralography	1		
Structural crystallography	8		
Geometrical crystallography	7		
Petrography	10		
Memorials, miscellaneous	7		
	<hr/> 62	695	85
Proceedings of societies	28	41	15
Short articles	29	58½	
Notes and news	15	7	
Abstracts of new mineral names	18	6	
Book reviews	13	10½	
<i>Total of text</i>	<hr/> 165	<hr/> 818	<hr/> 100
Illustrations	268		
Covers, advertisements, index		122	
<i>Total</i>		<hr/> 940	

Respectfully submitted,

WALTER F. HUNT, *Editor*

## REPORT OF THE TREASURER FOR 1936

*To the Council of the Mineralogical Society of America:*

Your Treasurer submits herewith his annual report for the year beginning December 1, 1935, and ending November 30, 1936.

## RECEIPTS

Cash on hand December 1, 1935	\$3,080.80
Dues and subscriptions	2,294.07
Advertisements	467.63
Sale of back numbers	359.23
Authors' charges on separates	456.33
Interest on endowment	2,349.50
Sale of 20-volume index	146.50
Geological Society of America grant for 1936	1,500.00
Partial payments on principal of Certificates, The Trenton	
Mortgage and Title Guaranty Co.	<hr/> 248.60
	\$10,902.66

## DISBURSEMENTS

Printing and distribution of the Journal (12 issues) . . . . .	\$5,095.93	
Printing and distribution of separates . . . . .	679.73	
To the Editor, Secretary, and Treasurer . . . . .	907.50	
Postage . . . . .	121.64	
Printing . . . . .	77.92	
Stationery . . . . .	12.90	
Clerical help . . . . .	206.87	
Committee expenses . . . . .	2.40	
Safety deposit box . . . . .	8.25	
Bank collecting charges . . . . .	3.40	
Telegrams . . . . .	1.26	
Check returned . . . . .	34.38	
Refunds on authors' separates . . . . .	5.95	
Printing of 20-volume index . . . . .	509.61	
Roebbling Medal Fund . . . . .	100.00	
Cash from partial payments on principal of Certificates, The Trenton Mortgage and Title Guaranty Co. . . . .	248.60	
	<u>\$8,016.34</u>	
Cash balance November 30, 1936 . . . . .	<u>\$2,886.32</u>	
		\$10,902.66

The partial payments on the principal of the Certificates of the Trenton Mortgage & Title Guaranty Co., of Trenton, N. J., namely \$248.60 have been converted into cash and placed with the Certificates.

The endowment funds of the Society as of November 30, 1936 consist of the following securities:

4 \$100 bonds, Great Northern Railway Co., Genl. mtg., 5½%, due January 1, 1952 . . . . .	\$	400.00
1 \$500 bond, Union Pacific R. R., Lien and ref. mtg., 4%, due June 1, 2008 . . . . .		500.00
1 \$1,000 bond, The Denver Gas and Electric Light Co. First and ref. mtg., 5%, due May 1, 1951 . . . . .		1,000.00
2 \$1,000 Certificates, The Trenton Mortgage and Title Guaranty Co., First mtg., 5½%, due November 1, 1937 . . . . .		2,000.00
2 \$1,000 Certificates, The Trenton Mortgage and Title Guaranty Co., First mtg., 5½%, due April 1 and December 1, 1938 . . . . .		2,000.00
45 \$1,000 bonds, City and County of Honolulu, Hawaii, Water Works, 5%, due April 15, 1954 . . . . .		<u>45,000.00</u>
		\$50,900.00

In addition, there is \$300.00 in U. S. Postal Savings bonds, and \$100.00 in cash, a total of \$400.00, laid aside for the Roebbling Medal Fund.

Respectfully submitted,  
WALDEMAR T. SCHALLER, *Treasurer*

Statement of Special Dana Fund of the Mineralogical Society of America, initiated by Professor E. S. Dana, and since his death cared for by the Treasurer. Disbursement made to the daughter of Professor F. Berwerth in Vienna, Austria.

## RECEIPTS

Available balance November 30, 1935.....	\$1,397.71	
Interest.....	34.24	
Contribution.....	10.00	
		<hr/>
		\$1,441.95

## DISBURSEMENTS

Disbursed.....	\$ 180.00	
Available balance November 30, 1936.....	1,261.95	
		<hr/>
		\$1,441.95

## REPORT OF THE AUDITING COMMITTEE

*To the President of the Mineralogical Society of America:*

The Auditing Committee has examined and verified the accounts and report of the Treasurer for the fiscal year ending November 30, 1936. The securities listed in the Treasurer's report are in the safety deposit box at the American Security and Trust Company of Washington, D. C. All future coupons on the coupon bonds are attached. In addition there is in the box \$300.00 in U. S. Postal Savings Bonds and \$100.00 in cash laid aside for the Roebling Medal Fund. There is also in the box \$248.60 in cash, representing payments on the principal of the certificates of the Trenton Mortgage and Title Guaranty Company together with said certificates (registered).

Respectfully submitted,

NORMAN L. BOWEN, *Chairman*  
JEWELL J. GLASS  
THOMAS B. NOLAN



## PRESIDENTIAL ADDRESS

The address of Dr. William S. Bayley, retiring President of the Mineralogical Society of America, was given Tuesday, December 29, 1936 at 11:40 A.M. in the Hall of Mirrors, before the joint assembly of all societies. Dr. Bayley's address was entitled "Mineralogy's Contribution to the Other Sciences and to Industry."

## PRESENTATION OF PAPERS

## MINERALOGY, PHYSICAL-CHEMICAL MINERALOGY, AND CRYSTALLOGRAPHY

*Tuesday Afternoon, December 29th*

(1) THE SYSTEM,  $\text{NaAlSi}_3\text{O}_8\text{--FeO--SiO}_2$ , by Norman L. Bowen.

In a system with the above components fayalite and albite are binary compounds. The results of a study of mixtures of fayalite and albite have already been published. The join, fayalite-albite, divides the general triangle into two parts in one of which there is a ternary eutectic between fayalite, albite and silica, with a temperature of  $980^\circ$  and containing only some 5 per cent fayalite. In the other portion of the triangle there are certain complications due to the appearance of the oxide phases wustite and hercynite but in the area where these phases do not appear there is a ternary eutectic between nepheline, albite and fayalite with a temperature of  $990^\circ$  and containing only some 10 per cent of fayalite. These mixtures are not unrelated to certain soda-rich rhyolites, trachytes and phonolites and the determinations throw some light on the genesis of such rocks.

## (2) OBSERVATIONS ON THE PRODUCTION OF SYNTHETIC GEMS, by Edward H. Kraus.

Observations made at the plants at Locarno, Switzerland, and Bitterfeld, Germany, where synthetic gems are manufactured, were summarized. Certain phases of the process of manufacture and some of the characteristic properties of synthetic ruby, sapphire, spinel, and emerald, were discussed.

## (3) FURTHER STUDIES OF THE ZEOLITES, by A. N. Winchell.

The square diagrams previously used to represent the variations in composition in zeolites have been corrected and modified to include new data. As before, they show that zeolites vary in composition chiefly in the same way as feldspars. They also show that the variation consists essentially in the addition of silica. Accordingly, it is possible to consider these variations in terms of the *three* molecules:  $\text{CaAl}_2\text{O}_4$ ,  $\text{Na}_2\text{Al}_2\text{O}_4$ , and  $\text{Si}_2\text{O}_4$ . This makes it possible to represent the composition of all zeolites on ternary diagrams, which are more satisfactory than the square ones previously used. Finally, variations in optical properties corresponding with these variations in composition are not easily defined, because variations due to other causes are commonly present, but a diagram for thomsonite has been prepared.

## (4) THE TREND OF MINERALOGICAL RESEARCH, by W. A. Tarr.

The attempt is made in this paper to determine the trend in mineralogical research by an analysis of the leading articles in *The American Mineralogist* and the *Mineralogical Magazine* for the last two decades. The material in the two journals is classified under several heads, such as physical properties, crystal structure and  $x$ -rays, chemical mineralogy, origin, and descriptive mineralogy. The analysis reveals an interesting distribution of the subject matter, and evidence of certain fairly definite trends.

(5) UNGEMACHITE AND CLINO-UNGEMACHITE—NEW MINERALS FROM CHILE, by M. A. Peacock and M. C. Bandy.

Ungemachite is rhombohedral— $\bar{3}$ ;  $a:c=1:2.2966$ ;  $\alpha=62^\circ 51\frac{1}{2}'$ ; thirty forms. Habit, thick tabular {0003} {111}. Cleavage {0003} {111} perfect.  $a_0=10.84\pm 0.02$  Å,  $c_0=24.82\pm 0.05$  Å;  $a_0:c_0=1:2.290$ ;  $V_0$  (rhombohedral cell)=842 cubic Å. Cell content:  $\text{Na}_8(\text{K}, \text{Fe}''')_4(\text{OH})_2(\text{SO}_4)_6\cdot 10\text{H}_2\text{O}$ , with  $\text{K}:\text{Fe}'''$  about 3:1.  $\text{H}=2\frac{1}{2}$ .  $G=2.287\pm 0.003$  (Berman). Colourless, transparent; uniaxial, negative;  $n_O=1.502$ ,  $n_E=1.449$ . Analysis (Gonyer):  $\text{Na}_2\text{O}$  21.61,  $\text{K}_2\text{O}$  11.35,  $\text{Fe}_2\text{O}_3$  7.69,  $\text{SO}_3$  40.23,  $\text{H}_2\text{O}$  16.69,  $\text{N}_2\text{O}_5$  trace, insol. 2.07, sum 99.64. Occurs with sideronatrite in massive altered iron sulphates at Chuquicamata, Chile. Named in honour of the late Henri Ungemach of Strasbourg.

Clino-ungemachite is monoclinic;  $a:b:c=1.6327:1:1.7308$ ;  $\beta=110^\circ 40'$ ; twenty-four forms; lattice {100} centered. The simple lattice is pseudo-rhombohedral, very like that of ungemachite, with which it is intimately associated. The properties are close to those of ungemachite, but the material is insufficient for a chemical analysis.

(6) PARAGENESIS OF THE URANIUM-BEARING AND ASSOCIATED MINERALS OF THE RUGGLES' PEGMATITE NEAR GRAFTON CENTER, NEW HAMPSHIRE, by Benjamin M. Shaub.

Recent work in mining for feldspar at the Ruggles' pegmatite has exposed numerous uranium-bearing and rare-earth minerals. The uraninite occurs as a three-dimensional dendritic intergrowth in plagioclase feldspar and closely associated with apatite. The alteration of these is attended with a group of hydrous uranium-bearing phosphates. Galena and other sulphides are sparingly present with the original minerals of this group. Beryl is apparently absent, however, in lower openings along the strike down the mountain, but undoubtedly a continuation of the main pegmatite mass, it occurs sparingly. On an older dump pieces of lithiophyllite intimately associated with pyrrhotite, chalcopyrite and other sulphides weighing up to 50 pounds were found. More than 30 mineral species are already known from this mineral deposit. The pegmatite mass is intruded into strongly metamorphosed schists along their strike, but it often cuts sharply across the foliation. Both are cut by later diabase dikes.

(7) THE CRYSTAL STRUCTURE OF KRENNERITE, by George Tunell and C. J. Ksanda

Well-developed faceted crystals of krennerite from Cripple Creek, Colorado, previously measured by Dr. M. A. Peacock on the two-circle reflection goniometer, were investigated by means of the Weissenberg X-ray goniometer. The dimensions of the unit cell were found to be:  $a_0=16.51$  Å,  $b_0=8.80$  Å,  $c_0=4.45$  Å, all  $\pm 0.03$  Å. The unit cell contains 8 "molecules" of  $\text{AuTe}_2$ . The systematically missing spectra limit the space-groups possible for krennerite to three, namely,  $Pmc-C_{2v}^2$ ,  $Pma-C_{2v}^1$ , and  $Pmma-V_h^8$ . From an analysis of the intensities of the diffraction spots on our Weissenberg negatives, from consideration of the close relationship between the structural lattices of krennerite and calaverite as determined by our Weissenberg studies of single crystals, and from the close similarity of the powder photographs of the two minerals both as to positions and intensities of the diffraction lines, the atomic arrangement in krennerite must be one that is isomorphous with the space-group  $Pma-C_{2v}^1$ . The values of the 18 parameters were determined from the intensities alone. The structure of krennerite is closely related to that of calaverite although the two minerals crystallize in different systems.

(8) A MINERALOGIC STUDY OF SILICOSIS, by R. C. Emmons and R. Wilcox.

The observation has been made repeatedly that certain mineral associations with quartz render dusts harmless from the silicosis viewpoint. An attempt has been made to learn the

underlying principles. Experiments have also been carried out to learn what other minerals may cause silicosis.

(9) AN UNUSUAL FELDSPAR FROM THE NORTHERN INYO RANGE, by George H. Anderson and Donald D. Maclellan. (Geological Society Project.)

In studying thin sections of Boundary Peak granite from the Northern Inyo Range Dr. Anderson noted the occurrence in considerable abundance of an untwinned optically positive feldspar of lower birefringence and index than albite. These grains are commonly fringed with myrmekite wherever they are in contact with plagioclase.

Dr. Maclellan undertook a detailed study of the optical properties of the feldspar with the aid of the universal stage. This yielded the following results:

Crystal system, triclinic. Extinction angles:  $X$  on best cleavage (probably 001),  $7^\circ$  to  $10^\circ$ ;  $Z$  on second best cleavage (probably 010),  $10^\circ$  to  $15^\circ$ . Optic angle variable, mostly ranging from  $80^\circ$  to  $86^\circ$  but in a few grains as low as  $64^\circ$  and in one or two as high as  $89^\circ$ . Indices:  $N_g = 1.524$ ,  $N_m = 1.520$ ,  $N_p = 1.518$ . Birefringence = .006.

An  $x$ -ray study undertaken by Dr. Linus Pauling and Dr. J. H. Sturdivant confirmed the triclinic character of the mineral and showed that it is distinctly different in several respects from both microcline and orthoclase.

Since the mineral can be distinguished from ordinary feldspars only in thin section, material for analysis could be secured only by digging individual grains from sections slightly thicker than standard. It was practically impossible to secure sufficient amounts for chemical analysis, but a quantitative spectroscopic determination by Dr. Maurice Hassler showed the following composition:  $K_2O$ , 11%;  $Na_2O$ , 2.7%;  $CaO$ , 0.3%;  $BaO$ , approximately 0.5%;  $SrO$ , approximately 0.01%;  $MgO$ , approximately 0.02%,  $Fe_2O_3$ , approximately 0.04%.

The mineral is therefore a positive triclinic potassic feldspar different in several respects from any other described species.

(10) THE VALENCES OF IRON IN PYRITE AND MARCASITE, by M. J. Buerger.

A determination of the crystal structure of arsenopyrite has shown that the iron atom has a radius of  $1.13 \text{ \AA}$ , which is smaller than its generally accepted radius,  $1.24 \text{ \AA}$ , while the sulfur atom has a radius of  $1.10 \text{ \AA}$ , which is correspondingly larger than its generally accepted radius,  $1.04\text{--}1.06 \text{ \AA}$ . The sulfur and iron radii in arsenopyrite are the same as those found in marcasite and löllingite. They differ from the values found in any other group of crystals including the pyrite group. An extrapolation of the radii of transition metals given in tables by Pauling and Huggins shows that the radius of iron in the marcasite packing is just what would be expected if the iron atom were in the ferric state rather than in the ferrous state as it is in pyrite.

The parameter values for sulfur in marcasite which control the calculated sizes of the atoms in that crystal have been criticized by Pauling and Huggins because the atom radii values do not correspond with the accepted values. The marcasite parameters have therefore been completely redetermined using the unequivocal new Weissenberg methods. All possible planes  $hk0$  and  $h01$  which can be recorded with  $MoK\alpha$  radiation have been registered on both underexposed and overexposed Weissenberg equator films for the purposes of comparing strong and weak reflections respectively. A complete study of the variation of these intensities with parameter change has also been carried out. The results completely confirm the earlier study of marcasite, and it can be confidently affirmed that marcasite has a small iron atom and a large sulfur atom.

It therefore appears that the iron in pyrite and marcasite is in different valence states: pyrite is ferrous disulfide while marcasite is ferric disulfide. This gives an entirely new

meaning to the Stokes test for pyrite vs. marcasite, and a possible new significance to the differential genesis of these two forms from different chemical environments.

- (11) A RARE-ALKALI BIOTITE FROM KINGS MOUNTAIN, NORTH CAROLINA, by Frank L. Hess and Rollin E. Stevens.

The paper concerns the occurrence of biotite containing rare alkali metals, associated with mica schists bordering pegmatites. Dark mica, developed notably in mica schist at the contact with a pegmatite, both at Tin Mountain, South Dakota, and Winterham, Virginia, were found to contain small quantities of lithium, caesium, and rubidium. These two occurrences suggested that where dark mica was found developed at the border of a pegmatite, especially one carrying lithium minerals, it should be examined for rare alkali metals.

In the examination of spodumene bearing pegmatites, enclosed in mica schists, from Kings Mountain, North Carolina, brownish mica was found which was supposed to have come from the schist at its contact with the pegmatite. The pegmatite with which the mica is associated is unusual in that dark minerals are exceedingly scarce. Spodumene makes up 15 to 20% of the mass.

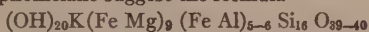
The composition of the Kings Mountain biotite as compared to that from Tin Mountain, South Dakota, shows less iron and more silica. The percentages of alkali oxides present are almost identical. The quantity of fluorine present seems to explain why the border biotites carry the alkali metals usually found in the zones of highest temperature. Some fluorides are notably soluble at comparatively low temperatures and it seems probable that the alkali metals were carried as fluorides to the sides of the pegmatites and there entered into the biotites of the enclosing schists.

- (12) THE SYMMETRY OF ICE, by Austin F. Rogers.

A careful study of ice and snow crystals and their solution forms indicates that ice belongs to the dihexagonal pyramidal class ( $A_6 \cdot 6P$ ) of the hexagonal subsystem. This determination of the symmetry is confirmed by the  $x$ -ray work of Bernal and Fowler.

- (13) SOME NOTES ON THE STRUCTURE OF STILPNOMELANE, by John W. Gruner.

Eight analyses of stilpnomelane suggest the formula



Five of the eight were  $x$ -rayed, three of them not being available. The photographs suggest a layer structure similar to chlorite and mica with the following dimensions:  $a=5.4 \text{ \AA}$ ,  $b=9.3 \text{ \AA}$ ,  $c=24.1 \text{ \AA}$ . This unit cell contains two molecules of the formula above. So far it has been impossible to arrange sheets of the mica, brucite, or kaolinite type in such a way that the intensities of the basal reflections in the photographs can be explained satisfactorily. Many plausible combinations have been tried. Also heating of the mineral up to  $740^\circ\text{C}$ . has offered no clue. It is stable at temperatures at least as high as  $500^\circ\text{C}$ ., but at  $600^\circ\text{C}$ . the structure is partly destroyed. A shrinkage from  $24.1 \text{ \AA}$  to about  $22 \text{ \AA}$  in the direction normal to the cleavage occurs at this temperature.

- (14) CRISTOBALITE AT CRATER LAKE, OREGON, by Carl E. Dutton.

Although cristobalite is not uncommon in the andesites of the Cascade Mountains, the occurrence at Crater Lake is somewhat unusual because of the well developed complete and skeletal octahedrons.

- (15) THE CRYSTALLOGRAPHIC SERIES OF BAUMHAUER AND UNGEMACH, A THEORETICAL CONSEQUENCE AND FACTUAL CONFIRMATION OF THE LAW OF BRAVAIS, by J. D. H. Donnay.

Ungemach, after Baumhauer, showed that, if the axial elements are correctly chosen, the main faces of a crystalline species are distributed in "series" covering the principal



half-zones. E.g.: series (011), (021), (031), (041), . . . covers the segment of zone [100] that extends from (011) to (010); series (011), (012), (013), (014), . . . covers the segment (011)–(001) of the same zone. Such “simple primary” series are obtained by adding the indices of the “pole,” i.e. (001) in the latter case and (010) in the former, to the indices of the starting face, i.e. (011) in both examples. The series may be of different types, according to Ungemach’s observations. Example of a double primary series:  $011 \cdot 031 \cdot 051 \cdot \dots$ , with (020) as its pole. Example of a simple secondary series:  $032 \cdot 052 \cdot 072 \cdot 092 \cdot \dots$ ; forms of the secondary series are obtained by addition of indices of two consecutive faces in a primary series. Secondary forms have been observed among the first members of otherwise normal primary series. The type of series found depends on the mode of centering of the (morphological) lattice.

Such empirical observations are shown to be direct consequences of the Law of Bravais. It is possible to predict what types of series are to be expected in the various half-zones, for different lattice modes. This affords easy criteria for the determination of the (morphological) lattice and “correct” axial elements.

(16) CHECKING INDEX LIQUIDS WITH THE MICROSCOPE, by C. B. Slawson.

The index of refraction of a liquid is measured with a microscope so constructed that the tube can be inclined to the side through an arc of  $10^\circ$ . The range of the index of refraction determinations extends from 1.330 to 1.880. A slit diaphragm placed in the condenser converts it into a collimating system and the microscope with the Bertrand lens inserted and an objective of proper focal length becomes a telescope. It then functions as a goniometer. A microscope slide with an accurately beveled edge placed upon a second slide forms the hollow glass prism which holds a few drops of the liquid.

(17) ON NORMAL TRICLINIC FACE-SYMBOLS AND THE HARMONIC-ARITHMETIC RULE, by M. A. Peacock.

If the Law of Bravais were strictly true, as applied to the simple structural lattice, the gnomonic projection points of the faces in a zone-quadrant would form the simultaneous series:

$$\begin{array}{ccccccccccc}
 0 \dots \frac{1}{3} & & \frac{1}{2} & & 1 & & 2 & & 3 \dots \infty \\
 0 & \dots & (\frac{2}{3}) & & \frac{2}{3} & & (\frac{3}{2}) & & \frac{3}{2} & & (\frac{4}{3}) \dots \infty \\
 0 & & \dots & \frac{3}{5} & \frac{3}{4} & & (\frac{3}{3}) & & \frac{4}{3} & & \frac{5}{3} \dots \infty \\
 & & & & & & \dots & & & & 
 \end{array}$$

in which the end terms represent the planes with the greatest and second greatest spacings while the unit term represents the plane with the third greatest spacing in the quadrant. These *normal series*, corresponding to *normal face-symbols*, are harmonic from unity to zero, arithmetic from unity to infinity. The Law of Bravais predicts the relative extent of the several series in any one zone, and the degree to which either the harmonic or the arithmetic part may preponderate.

Analysis of a sufficient number of highly developed triclinic zones reveals a fair approach to the ideal series. In spite of irregularities, which constitute exceptions to the Law of Bravais, the proposed *Harmonic-Arithmetic Rule* leads unambiguously to the structural lattice, when applied to the gnomonic projection of the forms of a triclinic crystal on the plane normal to the axis of the main zone.

(18) THE WEISSENBERG TREATMENT OF CRYSTALS BELONGING TO THE OBLIQUE SYSTEMS, by M. J. Buerger.

The angles between planes in a crystal may be determined in a number of ways by the Weissenberg method. These include (1) the direct determination of the angle on the Weissenberg film, between the Z lines containing the orders of reflection of the two planes on

the equatorial photograph, and (2) the determination of the offsets of dome reflections on  $n$ -layer films as compared with the lines of corresponding pinacoid reflections on the equatorial film. Neither of these methods is accurate unless the Weissenberg translation motion is impracticably long. A method of extreme precision is the following: In a monoclinic crystal, the reciprocal lattice vectors,  $a^*$ ,  $c^*$ ,  $c^*-a^*$ , form a triangle, one of whose angles is the crystallographic element  $\beta$ . Measurements of the Bragg angles of reflection from the planes (100), (001), and ( $\bar{1}01$ ) will therefore yield data which will permit a calculation of  $\beta$  with the same precision as the other cell constants. A similar method may be used to calculate any interfacial angle. In triclinic crystals, this calculation does not yield the angles  $\alpha$ ,  $\beta$ , and  $\gamma$  directly, but rather the polar angles  $\lambda$ ,  $\mu$ , and  $\nu$ , from which  $\alpha$ ,  $\beta$ , and  $\gamma$  may be calculated by the familiar Goldschmidt polar form relation. The development of a new instrument (mentioned in another abstract) for the extremely accurate determination of lattice spacings, now makes it possible to determine not only the cell edges, but also their angles of inclination and, of course, the axial ratio, with an accuracy exceeding that of optical goniometer methods. The new  $x$ -ray methods have the additional advantage that they can be applied to crystals with incomplete form development and crystals whose perfection is too low to permit ordinary optical goniometer work with any accuracy.

(19) ENANTIOMORPHOUS QUARTZ IN TECTONITES, by H. W. Fairbairn.

A statistical analysis was made of the orientation of quartz from a Cambrian quartzite in southern Quebec. Approximately 10,000 grains were measured from 19 thin sections, collected over a strikewise distance of 14 miles. The most prominent maxima in the orientation diagrams (loci of greatest orientation of quartz axes) correspond to Maximum IV of Sander (see D. 61 in *Gefügekunde der Gesteine*), and all four are symmetrically placed with respect to the projection line of the quartzite foliation surfaces. This maximum has not yet been satisfactorily explained and the following interpretation is offered. Gliding occurred parallel to rhombohedral planes of the quartz. The glide directions in these planes are not, as is usual, in a plane containing the vertical crystallographic axis, but are oblique, with a statistical arrangement which corresponds to the trapezohedral symmetry of enantiomorphic quartz. Two of the maxima in the diagrams originate from right-handed grains; two from left-handed. Since the structure of low-quartz is still uncertain it is not yet possible to correlate these assumed glide directions with known directions of greatest atomic density.

(20) THE STAUROLITE BELTS OF PATRICK AND HENRY COUNTIES, VIRGINIA,\* by Charles H. Moore, Jr.

The staurolites in these two counties occur in two roughly parallel belts. One belt begins at a point four miles southwest of Stuart and extends in an approximate N 50 E direction for a distance of about nineteen miles. The other begins at a point nine miles northeast of Stuart and one-half mile southeast of the first belt and extends to and beyond the Franklin County line. The belts are roughly lenticular in shape and have a maximum width of two and one-half miles.

The three principal rocks associated with the staurolites are a biotite chlorite schist, a sericite staurolite schist, and an iron-stained quartz mica schist. These rocks form a portion of the Wissahickon formation where the Martic overthrust block overrides the Lynchburg gneiss. They form a sharp contact with the Lynchburg gneiss along their western boundary and grade into less metamorphosed Wissahickon on the east.

The staurolites occur as reddish brown idioblastic crystals one-tenth inch to one and one-half inches in length in each of the three rock types, and are altered wholly or in part

\* By permission of the Virginia Geological Survey.

to sericite or chlorite. They contain numerous inclusions of small garnets which weather out, giving the appearance of pits in the staurolite crystals. The staurolites appear to be most numerous near the ends of the lenticular belts.

- (21) HELIUM RATIO OF FLORIDA ANHYDRITE, by William D. Urry. (Geological Society Project.)

The rate of production of helium from the radioactive elements uranium and thorium being constant, a determination of these elements and the helium in rocks and minerals affords a measure of their age. Determinations have so far been confined to igneous rocks with the exception of the anhydrite here reported. The anhydrite drill core was taken from the South Lake Well, Florida, from a deposit 180 feet thick, at a depth of 2560 feet, the well starting in the Ocala limestone. Stratigraphic evidence places it most probably in the earliest Eocene and the computed age  $71 \pm 6$  million years—late Cretaceous to early Eocene compared with the time scale from the igneous rocks—is in good accord with the stratigraphic evidence. If such agreement is borne out in further work the application of the method to the field of minerals will greatly aid in the solution of chronological problems of mineralization.

#### MINERALOGY, PETROGRAPHY, AND PHYSICAL-CHEMICAL MINERALOGY

*Wednesday, December 30th*

- (22) THE DISTRIBUTION OF LITHIUM IN ROCKS AND MINERALS AS REVEALED BY QUANTITATIVE SPECTRUM ANALYSIS, by Lester W. Strock.

The material presented is the result of a study of the Geochemistry of Lithium made in the Laboratory of Prof. V. M. Goldschmidt at Göttingen University. A specially accurate quantitative method of optical spectrum analysis was devised capable of determining lithium to an accuracy of  $\pm 3\%$  in the range 0.0001 to 3.5%  $\text{Li}_2\text{O}$ . The method will be briefly outlined. The amount of  $\text{Li}_2\text{O}$  in all the various types of primary, sedimentary, and some metamorphic rocks was determined. After determining the  $\text{Li}_2\text{O}$  content of sea water, the geochemical balance was calculated by the method of Prof. V. M. Goldschmidt. The most interesting results were obtained by analyzing the individual mineral components of rocks separately, which furnish one of the most excellent examples known for the important manner in which the laws of crystal chemistry may be applied in explaining isomorphism in minerals. The entire study illustrates the excellent service which quantitative spectrum analysis can render to mineralogy.

- (23) UNUSUALLY HIGH FELDSPAR CONTENT OF THE GLENWOOD FORMATION, by John W. Gruner.

The Glenwood formation is of Ordovician age. Near Minneapolis it consists of a number of beds of clayey material which contain well rounded quartz grains all of which appear to be larger than 1/10 mm. The material smaller than this size was analyzed chemically and by  $x$ -rays. This fine material of one of the beds consists chiefly of potash feldspar. As a matter of fact, enough potash is present for two-thirds of the material to be feldspar.  $X$ -rays give the feldspar pattern only, even for sizes as small as one micron. Below this dimension many of the diffraction lines become very broad. While the feldspar pattern still persists, diffusion bands common to amorphous substances appear. The extremely small size of the feldspar particles raises the question as to the genesis of them. It is not thought likely that they represent simply a disintegration product of large crystals. The feldspar is probably secondary like authigenic material though no nuclei were necessary for its formation.

(24) THE PLANTERSVILLE METEORITE, GRIMES COUNTY, TEXAS, by John T. Lonsdale.

The Plantersville meteorite fell on the afternoon of September 4, 1930, at a point  $3\frac{1}{2}$  miles southwest of Plantersville, Grimes County, Texas. The locality of the fall is forested but several men were working nearby and recovered the specimen within a few minutes of its fall. The phenomena of fall included rumbling explosions and a noise like an airplane in flight. This find is a light gray friable aerolite, weighing 2084.9 grams, with a dense black crust showing oriented thread lines. The shape is sub-conoid faceted with a well developed brustseit. The dimensions are  $5\frac{1}{4}'' \times 4'' \times 3\frac{1}{4}''$ , measured in three directions at right angles.

The texture of the meteorite is largely crystalline but glass is present in chondrules and also as an interstitial material in the groundmass. A relatively small number of minute veins of metal occur. Many chondrules are present most of which are angular or fragmental. The minerals present include hypersthene, chrysolite, a monoclinic pyroxene, metallic iron, troilite, black and colorless glass, and a reddish-brown spinel. Chemical and spectrographic analyses are included in the paper.

(25) ORIGIN OF THE CANADIAN APATITE-PHLOGOPITE DEPOSITS, by Kenneth K. Landes.

Apatite-phlogopite deposits in the watersheds of the lower Gatineau and Lievre rivers in southwestern Quebec, and one deposit near Wilberforce in southeastern Ontario, were examined. The pre-Cambrian metamorphic complex has been intruded by bodies of diopside "pyroxenite" with microcline pegmatite, accessory scapolite, actinolite, and titanite, and veins consisting principally of calcite, phlogopite, and apatite. The theory is advanced that a granite pegmatite magma on its way upward became contaminated through the assimilation of dolomite. Diopside first crystallized from this magma, partially desilicating it, and then the microcline pegmatite with accessory scapolite, actinolite, and titanite was formed. Calcite, phlogopite, and apatite resulted from a hydrothermal phase. The pyroxenite bodies and the country rock are alike cut by much later dikes of white microcline-quartz pegmatite.

(26) CRYSTALLOGRAPHY OF SYNTHETIC BURKEITE, by Lewis S. Ramsdell.

Crystals of synthetic burkeite,  $2\text{Na}_2\text{SO}_4 \cdot \text{Na}_2\text{CO}_3$ , have been obtained by evaporation from solution at 70–80°C. The crystals are usually twinned, but single individuals occur occasionally. Goniometric measurements give an axial ratio of 0.534:1:0.750. The usual forms present are (110) and (111). The twins consist of trillings, with (110) as the twinning plane.

(27) THE TERNARY SYSTEM, LEUCITE-DIOPSIDE-SILICA, by J. F. Schairer.

The field of diopside occupies a large portion of the phase diagram of the ternary system and diopside is the primary phase in some compositions with less than two per cent by weight of that compound. The ternary eutectic (solid phases—diopside, tridymite, orthoclase) and the ternary reaction point (solid phases—leucite, orthoclase and diopside) lie at compositions very close to the binary eutectic and binary reaction point in the system, leucite-silica. The field of orthoclase is very small. Residual liquids in fractional crystallization are rich in alkali-alumina silicates.

(28) LAMPROPHYRES OF THE BAY OF EXPLOITS, NEWFOUNDLAND, by George R. Heyl.

A group of lamprophyre dikes, chiefly monchiquites and fourchites, occur in the Bay of Exploits area of northeastern Newfoundland. Their spatial distribution indicates that they are genetically connected with the granodiorite batholiths of the region. They are the youngest intrusive rocks in the area and represent the final stage of the batholith differentiation.



The large phenocrysts of biotite and hornblende present in these dikes show pronounced evidences of resorption and reaction, indicating that they were unstable in the magma at the time of its intrusion. One of these dikes contains a great number and variety of inclusions which likewise show marked reaction and resorption effects. The reactions are of a type which would occur with an abrupt drop in pressure. Many of these dikes show fine-grained or aphanitic selvages which are interpreted as the chilled facies.

The evidence indicates that the lamprophyres were intruded as a magma which in most cases contained some intratelluric crystals in suspension. The changes in thermodynamic conditions during the transfer and injection of the magma resulted in these crystals becoming unstable. The minerals that were stable at the time of freezing of the dikes were those which have crystallized in the groundmass. A relatively low temperature of freezing of these rocks is suggested by the abundance of primary analcite in them; this is corroborated by the lack of thermal metamorphism in the rocks immediately adjacent to the dike walls.

The lamprophyre magma is conceived to have formed by the interaction of the residual magma of a batholith with the more basic deep-lying portions of the batholith. A magma unusually rich in femic molecules and hyperfusibles would result. Of the hyperfusibles water was by far the most abundant; in addition there was a concentration of carbon dioxide, fluorine, chlorine, phosphorus and sulphur. Because of the concentration of hyperfusibles, the vapor tension would be high, and if it exceeded a certain limit the magma would be injected outward and upward into the surrounding rock. This would be accompanied by rapid transfer of material and an abrupt drop in pressure, and, upon freezing, lamprophyre dikes would result. Such a history is indicated by the lamprophyres of the Bay of Exploits.

(29) ORIGIN OF THE MARCASITE SINK-HOLE DEPOSITS OF CENTRAL MISSOURI, by W. A. Tarr.

There are ten known deposits of marcasite (and pyrite in small quantities) in sink-holes in Franklin, Crawford, and Phelps counties in the northeastern part of the Missouri Ozarks, and others probably exist. Only two are active producers, at present. These sulfide deposits occur in the lower part of the sink-holes, the upper part having been occupied by hematite which has been removed by mining. The sulfide reaches a maximum thickness of 30 feet in some deposits and may be approximately 200 feet wide. The overlying hematite was pseudomorphous after the sulfides. The marcasite is accompanied by masses of sandstone and quartz as the chief gangue minerals. The contact of the ore with the walls of the sink-hole is normally sharp, locally it is gradational. The marcasite is massive, mammillary, stalactitic, botryoidal, granular, crystalline, and porous.

It is believed that the deposits were formed by hydrothermal solutions which rose from a hidden igneous mass below and deposited sulfides in the sink-holes under a cover of Pennsylvanian shales. The hematite resulted from the oxidation of the upper portion of the sulfide mass.

(30) ORIGIN OF THE CHERT IN THE TRI-STATE (MISSOURI-OKLAHOMA-KANSAS) ZINC-LEAD DISTRICT, by Chalmer J. Roy.

Three types of siliceous rocks are found in association with the sulphide ores of the Tri-State district, namely, early chert, late chert and jasperoid. The early chert, occurring as nodules and nodular beds, is found in the Mississippian limestones throughout the Mississippi valley and is believed to have formed as a penecontemporaneous replacement of the limestone. The late chert, occurring as massive beds, veins and silicified fault zones in the mining area only, is definitely epigenetic. The jasperoid occurs in intimate association with the sulphides and is believed to be contemporaneous with them, but later than the late chert. The late chert and jasperoid are believed to represent two phases of the ore

mineralization, one (the late chert) early and barren of sulphides, the other later and containing abundant sulphides. Both are believed to be hydrothermal.

(31) THE MINERALOGY OF THE WISCONSIN LEAD-ZINC ORES, by Charles H. Behre, Jr.

Recent mineralographic studies of the Wisconsin lead-zinc ores have revealed relationships bearing on their origin. The recognized sequence, as in similar European districts, was iron sulphide (loosely designated "marcasite"), sphalerite, galena, late barite, accompanied by long-extended calcite and iron sulphide deposition. Banfield and Born showed that much of the "marcasite" was actually pyrite; both minerals are colloform and their relations and similarity in form suggest paramorphism of pyrite after marcasite. An almost constant feature is a thin film of pyrite between country rock and ore.

The zinc sulphide is also largely colloform and in long bladed crystals, thus resembling the Silesian "Schalenblende" (wurtzite). Its presence favors acid waters as depositing agents. Some arsenic is present but in what mineral is not known.

Barite is conspicuously late as compared with the sulphides, thus differing from that in peripheral deposits of typical meso- and epithermal ores. Some silicification is chert-like but whether primary or secondary is still uncertain. Calcite in scalenohedral forms cements shattered sphalerite or wurtzite and typifies the late form of the carbonate, as compared with the earlier, rhombohedral form.

The replacement ores are quantitatively negligible, fissure fillings preponderating. Structural relations of the ores are not here discussed in detail, but the resemblance to the Silesian zinc ores, both structurally and mineralogically, is striking.

(32) CLASSIFICATION OF THE NATURAL SILICATES, by Charles K. Swartz.

It is the author's purpose to bring together the results of *x-ray* analyses, thus far published, bearing upon the problem of the mutual relations and chemical composition of the natural silicates and to present a classification of the silicates based upon the data thus assembled.

The principles underlying the classification were briefly discussed. It was shown that there are five fundamental types of natural silicates whose character and composition were illustrated. It was shown further that these fundamental types may combine among themselves to produce more complex assemblages, a number of which have thus far been observed.

The relations of the classification here proposed to those of Bragg, St. v. Naray-Szabo and Machatschki were considered briefly.

A table was given showing the classification of the chief families of silicate minerals. A detailed table has been prepared and will be published later, giving the composition of the natural silicates whose structures have been determined by *x-ray* analyses up to the present time, together with literature citations.

(33) THE STRUCTURAL LATTICE AND CLASSIFICATION OF BUSTAMITE, by Harry Berman and Forest A. Gonyer.

Bustamite ( $\text{CaMnSi}_2\text{O}_6$ ) was formerly regarded as a lime rhodonite; more recently it has been considered as a manganese wollastonite. Since bustamite does not occur in faceted crystals it was not possible to help settle the question by morphological comparisons. *X-ray* measurements on a cleavage fragment yielded the following triclinic lattice dimensions:  $a_0 = 7.64 \text{ \AA}$ ,  $b_0 = 7.16 \text{ \AA}$ ,  $c_0 = 6.87 \text{ \AA}$ ;  $\alpha = 92^\circ 08'$ ,  $\beta = 94^\circ 54\frac{1}{2}'$ ,  $\gamma = 101^\circ 35'$ ;  $a_0:b_0:c_0 = 1.067:1:0.959$ . The values are close to those of wollastonite. An analysis of the studied material leads to the cell content:  $\text{Ca}_3\text{Mn}_3\text{Si}_6\text{O}_{18}$ , which compares with the cell content of wollastonite:  $\text{Ca}_4\text{Si}_4\text{O}_{18}$ . The present study thus shows that bustamite is a manganese wollas-

tonite, confirming the conclusion previously reached from optical study and powder photographs.

(34) VEIN-FILLING AT NEVADA CITY, CALIFORNIA,\* by W. D. Johnston, Jr.

A grant from the Penrose Bequest made possible the continuation in 1934 of work begun at Nevada City in 1931.

The principal ore minerals in the gold-quartz veins of Nevada City are pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, and tetrahedrite, with lesser amounts of molybdenite and gold. They were deposited in the earlier stages of vein-filling in a quartz gangue. In the later stages of vein-filling carbonates were the dominant gangue minerals. Galena, tetrahedrite, and gold were introduced late in the quartz sub-stage.

Unique in a district where most mines produce by weight more gold than silver, is the Central Mine of the Lava Cap Gold Mining Corporation where the ratio of gold to silver by weight is 1 to 12+ due to unusual abundance of argentiferous tetrahedrite. Pyrargyrite is found rarely in the Central Mine.

Quartz textures give some clue to vein history. Combs and massive homogeneous quartz indicate vein-filling without movement of the vein walls; breccias indicate movement with appreciable dilation of the interwall space; and shear structures, such as granulation zones in ribbon quartz and mortar structure, indicate movement without appreciable dilation of the walls.

Most veins show evidence of recurrent deposition of quartz alternating with movement of the walls. Thick veins have been built by alternation of quartz deposition and movement in which the hanging wall was at all times adequately supported.

\*By permission of the Director, U. S. Geological Survey, Washington, D. C.

(35) HORNFELS-GRANODIORITE TRANSITIONAL FACIES AT CORNUCOPIA, OREGON, by G. E. Goodspeed.

Metamorphic and granodioritic rocks of pre-Tertiary age, form the core of the rugged Wallowa mountains of northeastern Oregon. Near the mining town of Cornucopia, hornfels-granodioritic contacts are common and well exposed. In addition to excellent surface exposures these contacts have been intersected by several long adit tunnels at different elevations.

Transitional facies are found in irregular zones, dike-like and stock-like masses, breccias, and unusual occurrences of angular blocks of granodioritic rock surrounded by hornfels. Some of the transitional facies show first a gradual change from a porphyroblastic hornfels to a rock which would be classified as a porphyry. This grades into a gneissic granodiorite and finally to what would be called a normal granodiorite. In zones which have been affected by cataclastic metamorphism there may be relatively sharp hornfels-granodioritic contacts which may be explained by the selective recrystallization replacement of the crushed material.

It is believed that sufficient field and petrographic evidence has been accumulated to warrant the interpretation that these smaller granodioritic masses have been formed by recrystallization replacement incident to a process of additive dynamothermal metamorphism and that this interpretation may be extended to the larger granodioritic masses.

(36) THE UNIT CELL AND SPACE GROUP OF STERNBERGITE,  $\text{AgFe}_2\text{S}_3$ , by Newton W. Buerger.

Sternbergite from Joachimsthal, Bohemia, has been studied by the equi-inclination Weissenberg method. Due to the very plastic nature of sternbergite crystals this study has been very difficult and the cell constants given below are probably rough values. The

flexible nature of the crystals has also rendered the x-ray reflections poor, and certain other revisions may have to be made.

The investigation leads to the following cell data:

Diffraction symbol: mmmC-c-

Crystal class:  $C_{2v}$  or  $D_{2h}$

Crystal system: Orthorhombic

Space group: Cmc or Cmcm

Unit cell:

	Absolute	Ratio	Peacock's ratio
$a =$	11.7	1.74	.5913 ( $\times 3 = 1.7739$ )
$b =$	6.7	1.	1.
$c =$	12.67	1.88 <sub>6</sub>	.6250 ( $\times 3 = 1.8750$ )
$Z =$	8 $AgFe_2S_3$ per cell.		

It is evident that the axial ratio derived by surface morphological study should be altered so that  $b$  has  $\frac{1}{3}$  the length assigned to it by Peacock. This change also brings with it the necessity of interchanging the usual  $a$  and  $b$  axes in order to leave  $b$  the longer of the two.

The structural study of this crystal is being continued.

#### (37) 2E GONIOMETER, by Terence T. Quirke.

A goniometer is made in half-cylinder form, calibrated from  $0^\circ$  at the zenith to  $90^\circ$  at the base. It is used on the stage of an ordinary petrographic microscope using convergent polarized light for the sub-stage illumination. It is convenient to withdraw the barrel of the microscope so that the stage is clear of any obstruction to the placing of the goniometer. The mineral section to be measured must be cut at or near a plane normal to the acute bisectrix. The section is then placed in the  $45^\circ$  position so that the principal optic plane lies at  $45^\circ$  to the plane of vibration of transmitted light.

In the bottom of the goniometer there is a sheet of polaroid oriented at right angles to the vibration direction of the sub-stage polarized light. The polaroid is oriented in the position of the usual analyzer in the microscope but is placed immediately on top of the mineral section between the mineral section and the scale of the goniometer.

When this set up is placed in a dark room and strong light passed through the mineral section from the sub-stage polarizer the eyes of the two optic axes are projected onto the translucent scale of the goniometer where the angle 2E can be read directly.

#### (38) A UNIVERSAL STAGE METHOD OF DETERMINING BIREFRINGENCE, by R. C. Emmons.

With the purpose in mind of using birefringence as a determinative criterion of minerals when the identity is uncertain after other tests, a method has been developed for learning the birefringence in crystals unfavorably oriented for standard methods of measurement or in crystals of birefringence too high for standard accessories.

#### (39) SIMPLIFIED GRAPHIC METHOD OF DETERMINING APPROXIMATE AXIAL ANGLE FROM REFRACTIVE INDICES OF BIAXIAL MINERALS, by Harold T. U. Smith.

An adaptation of Wright's graphic plat for solution of the approximate equation makes possible the rapid determination of axial angle and optic sign directly from refractive indices. The necessity for first computing partial birefringences is eliminated. This method provides a convenient check on the consistency of laboratory determinations by the immersion method. Pedagogically, it serves to emphasize the mathematical interrelation between indices, axial angle, and optic sign.



- (40) A SYSTEM OF GRIDS FOR THE DETERMINATION OF NON-OPAQUE MINERALS, by J. D. H. Donnay and J. Mélon.

Existent determinative tables require that an unknown mineral be tested, at the outset of the procedure, for certain selected properties in a given order, e.g. optical anisotropy, optical character and sign, refractive index (Larsen-Berman); hardness, specific gravity (Rosenholtz-Smith); luster, fusibility (Brush-Penfield). Other properties serve only as a confirmation.

A new device (system of about 200 grids) extends the usefulness of existing tables: (1) It removes the necessity of adhering to any rigid order. (2) Any property may be used directly toward determination, which, therefore, rests mainly on the most striking properties. (3) All minerals in which any given set of properties co-exists are at once sorted out. (4) Even incomplete data regarding certain properties are usable. (5) At any point during the procedure one is guided in his choice of further tests. (6) The fact that a mineral is not included in the grids is automatically detected.

The device is applied to all non-opaque minerals (more than 1200). Its principle of construction has been described elsewhere.\* Its chief advantage lies in the mechanical aid it affords in determining minerals.

- (41) AN APPARATUS FOR THE PRECISION DETERMINATION OF SINGLE CRYSTAL LATTICE CONSTANTS, by M. J. Buerger.

None of the methods developed for the precise determination of lattice constants by powder methods is applicable to crystals more complicated than isometric or hexagonal because the diffraction loci of non-equivalent planes are, in general, unresolved. For the more complicated crystals the diffracted radiation must be obtained from a single crystal and recorded by one of the moving film methods. The Weissenberg arrangement is ideally suited to this purpose because it may include the entire range of reflections and because it provides for focussed spots over the entire range. The Sauter method lacks these advantages.

The instrument constructed for this purpose is one of the back reflection, absolute variety which takes advantage of the strategy: film shrinkage and other corrections  $\rightarrow 0$  as  $\theta \rightarrow 90^\circ$ . To do this, the x-ray beam must be introduced through the center of the Weissenberg film. To avoid film warping, the beam enters a small slot, and the translation motion of the film is reduced to 45 mm. A great deal of unused film is thus retained for strength, for a slot of only  $1\frac{1}{8}$  inches is used in a  $5 \times 7$  inch film. The camera proper has a radius of 57.26 mm. and the film is wrapped directly about the metal of the camera and unsupported only in the region of the one inch exposed section. The camera design is unique and avoids any accidental exposure of the film to light. The other features of the instrument design follow the standard equi-inclination Weissenberg apparatus, but simplified for this particular application, and made as rugged as possible. With the use of polychromatic radiation from duplex and triplex metal targets, extremely accurate lattice constants are determinable. A chart is presented for the purpose of identifying reflections on this type of instrument.

- (42) ON THE TIME REQUIRED TO FORM THE OLIVINE ZONE IN THE PALISADES SILL, NEW JERSEY, by John W. Butler, Jr.

Certain statistical petrologic studies offer quantitative information concerning differentiation and the consolidation history of igneous rocks. An application along this line reveals factors requiring consideration in computing the time necessary for gravitative

\* J. D. H. Donnay, *Système de grilles pour la détermination des minéraux: Annales de la Société géologique de Belgique*, 59, B 250-257, 1936.

differentiation to develop the conspicuous olivine zone near the base of the Palisades Diabase Sill, New Jersey.

Several thousand olivine grains were measured in a suite of thin-sections through the olivine zone. Most crystals have diameters of 0.1 mm. or less, few exceed 0.25 mm., and diameters greater than 0.5 mm. are rare in numerical comparisons. Many olivine crystals of all sizes are euhedral. Kind, occurrence, paragenesis, and size of associated minerals are significant also and are recorded.

The importance of detailed statistical observations is illustrated by size of olivine alone. A calculation of the time necessary to form the olivine zone, offered by Bowen, following Stoke's formula assumes olivine grains 0.7 mm. in diameter settled 200–300 meters through magma having viscosity of either 4.0, or, like some basic Hawaiian lavas, 0.5. The respective results were 200–300, and 25–40 hours. Recalculation, after substituting the diameter 0.25 mm. for 0.7 mm., gives values of about 1495–2242 hours, and about 190–285 hours respectively; substituting diameter of 0.1 mm. increases these last values about six times. Mean factors may be derived from petrologic observations throughout the sill.

Statistical tables emphasize the longer time necessary for this phase of gravitative differentiation which, however, was not completed. Subsequent intrusions into the olivine zone of diabase containing less olivine, and occasional deuterite, and hydrothermal effects may be traced through stages of their development.

*Thursday, December 31st*

(43) REFRACTIVE INDICES OF VITRAINS, by Terence T. Quirke and Louis C. McCabe.

The physical qualities of vitrain appear to vary according to the rank of the common banded coals which contain it. Variations in quality of vitrain are indicated by corresponding changes in the refractive index. The refractive indices of various vitrains range from about 1.60 to above 1.80.

Indices of refraction were computed from the angle of maximum polarization reflected from polished surfaces of vitrain. This has the advantage of avoiding the use of oils of high index of refraction, which are not only difficult to handle in many cases, but awkward to calibrate because their index lies beyond the range of the usual Abbe refractometer.

Determinations were made by means of a reflecting goniometer equipped with an analyzing nicol prism. Measurements were made not only from coal, but also from a series of minerals both transparent and nearly opaque, the indices of which have been determined by other methods.

(44) ACCURATE ORIENTATION OF THIN SECTIONS, by Earl Ingerson.

Accurate orientation of thin sections is becoming increasingly important in geologic work. Such orientation may be accomplished by use of a recently devised apparatus consisting of a small flat plate that may be placed against a relatively flat surface of hand specimen, and whose dip and strike may be read on graduated vertical and horizontal circles. This procedure orients the hand specimen and the plane of a desired thin section may be marked by using three movable arms that are in the plane of the measuring plate, and the dip and strike may be read on the graduated circles. The apparatus can be used for the following purposes:

1. To orient a hand specimen for laboratory study.
2. To measure the orientation of a plane surface other than the one marked (e.g. a joint plane).
3. To measure the direction and angle of plunge of a lineation.
4. To mark a plane (of a thin section) in a given position.

5. To measure the orientation of an *s*-plane or other plane that does not form a flat surface on the specimen.

Remarks on the marking of oriented sections were included.

(45) FLEXIBLE CRYSTAL MODELS, by Isay A. Balinkin.

The classification of crystal forms into seven fundamental systems can be conveniently demonstrated by means of a single flexible crystal model. It is constructed of 12 pieces of square tubing in a form of an open-sided cube. The junctions at the corners are made of specially designed balls and the model is held together with springs attached to the balls and passing through the tubing. This allows a free motion at each corner so that by a proper deformation all the basic crystal systems can be illustrated. The same model can also be changed into an octahedron, hexahedron, tetrahedron, twin triangular prisms, and twin hexahedra. Finally, it shows the space arrangement of the carbon atoms in graphite as distinguished from that in diamond. Other flexible crystal models such as dodecahedron, tetrakaidecahedron, etc., can be made using the same method of construction.

At various times during the sessions of the Society, the following persons registered their attendance. In addition, there were many others who visited sessions whose names were not recorded.

C. C. Albritton, Jr.	C. A. Chapman	F. B. Hanley
H. R. Aldrich	N. E. Chute	E. P. Henderson
V. T. Allen	L. C. Conant	D. F. Hewett
B. Alvarado	M. E. Cooley	G. R. Heyl
T. G. Andrews	G. W. Crickmay	A. P. Honess
E. T. Apfel	E. C. Dapples	W. F. Hunt
F. P. Atkins, Jr.	M. V. Denny	C. S. Hurlbut, Jr.
V. L. Ayres	R. M. Dickey	E. Ingerson
G. W. Bain	J. D. H. Donnay	W. B. Jewell
I. A. Balinkin	H. F. Donner	W. D. Johnston, Jr.
A. E. Barnes	C. E. Dutton	I. W. Jones
R. L. Barrett	M. L. Ehrmann	J. Jones
E. S. Bastin	B. C. Elsley	E. P. Kaiser
A. M. Bateman	R. C. Emmons	A. Keith
W. S. Bayley	G. T. Faust	P. F. Kerr
C. H. Behre, Jr.	C. R. Fettke	R. S. Knappen
H. Belyea	R. P. Fischer	A. Knopf
H. Berman	D. J. Fisher	P. W. Koller
J. C. Bierer	F. C. Foley	E. H. Kraus
M. H. Billings	F. Foreman	
K. E. Born		J. E. Lamar
N. L. Bowen		C. A. Lamey
W. R. Bradley	J. J. Glass	K. K. Landes
A. M. Brant	E. N. Goddard	H. C. Lee
E. L. Bruce	G. E. Goodspeed	J. T. Lonsdale
A. F. Buckham	R. G. Grassy	T. S. Lovering
A. F. Buddington	O. R. Grawe	Mrs. T. S. Lovering
M. J. Buerger	R. E. Grim	G. D. Louderback
N. W. Buerger	J. W. Gruner	G. F. Loughlin
F. Bullard	C. S. Gwynne	

W. K. MacFarquhar	A. B. Peck	A. K. Snelgrove
J. P. Marble	J. W. Peoples	A. B. Sperry
R. W. Marsden	E. L. Perry	K. Spiroff
J. H. C. Martens	S. S. Philbrick	T. Stadnichenko
E. B. Mathews	R. S. Poor	R. C. Stephenson
C. S. Maurice	F. H. Pough	D. Stewart, Jr.
W. J. McCaughey	W. E. Powers	M. Stow
H. E. McKinstry	A. Pyre	L. W. Strock
B. W. Meek		J. L. Stuckey
G. R. Megathlin	T. T. Quirke	C. K. Swartz
P. L. Merritt		
P. M. Miles	R. E. Radabaugh	W. A. Tarr
F. S. Miller	L. S. Ramsdell	Mrs. W. A. Tarr
R. B. Miller	H. Ries	E. Thomsen
W. J. Miller	J. Rodgers	E. Thomson
E. S. Moore	A. F. Rogers	W. N. Tipka
G. W. Morey	R. R. Rosenkrans	C. Tolman
F. K. Morris	C. S. Ross	G. Tunell
J. F. Morton	E. P. Rothrock	S. A. Tyler
E. S. Munyan	J. T. Rouse	
O. J. Myers	C. J. Roy	O. C. Von Schlichten
W. M. Myers	J. J. Runner	
		A. W. Waldo
R. B. Newcombe	E. Sampson	D. C. Wellman
A. H. Norton	A. E. Sandberg	A. M. Wellnitz
	J. F. Schairer	L. G. Westgate
D. T. O'Connell	W. T. Schaller	R. W. Whipple
A. R. Ostrander	B. M. Shaub	R. Wilcox
	C. B. Slawson	A. S. Wilkerson
C. Palache	C. M. Smith	S. S. Williamson
W. H. Parsons	H. T. U. Smith	A. N. Winchell
M. A. Peacock		H. Wuestner

## LIST OF FORMER OFFICERS AND MEETINGS WITH DATES

By recommendation of the Council, a complete list of past officers is printed in the proceedings of the annual meeting of the Society.

PRESIDENTS	VICE-PRESIDENTS
1920 Edward H. Kraus	1920 Thomas L. Walker
1921 Charles Palache	1921 Waldemar T. Schaller
1922 Thomas L. Walker	1922 Frederick A. Canfield
1923 Edgar T. Wherry	1923 George F. Kunz
1924 Henry S. Washington	1924 Washington A. Roebling
1925 Arthur S. Eakle	1925 Herbert P. Whitlock
1926 Waldemar T. Schaller	1926 George Vaux, Jr.
1927 Austin F. Rogers	1927 George L. English
1928 Esper S. Larsen	1928 Lazard Cahn
1929 Arthur L. Parsons	1929 Edward Wigglesworth
1930 Herbert E. Merwin	1930 John E. Wolff
1931 Alexander H. Phillips	1931 William F. Foshag
1932 Alexander N. Winchell	1932 Joseph L. Gillson
1933 Herbert P. Whitlock	1933 Frank N. Guild



1934 John E. Wolff  
 1935 Clarence S. Ross  
 1936 William S. Bayley

1934 W. A. Tarr  
 1935 Ellis Thomson  
 1936 Harold L. Alling

## SECRETARIES

1920-1922 Herbert P. Whitlock  
 1923-1933 Frank R. Van Horn  
 1933-1934 Albert B. Peck  
 1934- Paul F. Kerr

## TREASURERS

1920-1923 Albert B. Peck  
 1924-1929 Alexander H. Phillips  
 1929-1930 Albert B. Peck  
 1931- Waldemar T. Schaller

## EDITORS

1920-1921 Edgar T. Wherry  
 1922- Walter F. Hunt

## COUNCILORS

1920 Arthur S. Eakle, Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips.  
 1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.  
 1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.  
 1923 Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.  
 1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.  
 1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.  
 1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.  
 1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.  
 1928 William F. Foshag, William A. Tarr, Alexander N. Winchell, Ellis Thomson.  
 1929 William A. Tarr, Alexander N. Winchell, Ellis Thomson, Clarence S. Ross.  
 1930 Alexander N. Winchell, Ellis Thomson, Clarence S. Ross, Paul F. Kerr.  
 1931 Ellis Thomson, Clarence S. Ross, Paul F. Kerr, William S. Bayley.  
 1932 Clarence S. Ross, Paul F. Kerr, William S. Bayley, William J. McCaughey.  
 1933 Paul F. Kerr, William S. Bayley, William J. McCaughey, Kenneth K. Landes.  
 1934 William S. Bayley, William J. McCaughey, Kenneth K. Landes, E. P. Henderson.  
 1935 William J. McCaughey, Kenneth K. Landes, E. P. Henderson, J. F. Schairer.  
 1936 Kenneth K. Landes, E. P. Henderson, J. F. Schairer, Arthur F. Buddington.

## ANNUAL MEETING PLACES

1920 Chicago, Illinois  
 1921 Amherst, Massachusetts  
 1922 Ann Arbor, Michigan  
 1923 Washington, D. C.  
 1924 Ithaca, New York  
 1925 New Haven, Connecticut  
 1926 Madison, Wisconsin  
 1927 Cleveland, Ohio  
 1928 New York, N. Y.  
 1929 Washington, D. C.  
 1930 Toronto, Canada  
 1931 Tulsa, Oklahoma  
 1932 Cambridge, Massachusetts  
 1933 Chicago, Illinois  
 1934 Rochester, New York  
 1935 New York, N. Y.  
 1936 Cincinnati, Ohio.

CONSTITUTION AND BY-LAWS  
OF THE  
MINERALOGICAL SOCIETY OF AMERICA

CONSTITUTION

Article I. Name.

This Society shall be known as the Mineralogical Society of America.

Article II. Object.

The object of this Society shall be the advancement of mineralogy, crystallography, and allied sciences.

Article III. Officers.

*Section 1.* The officers of the Society shall be a president, a vice-president, a treasurer, a secretary, and an editor, who shall be elected annually. There shall be an executive council consisting of the above officers, the retiring president, and four fellows at large, to be elected for terms of four years each.

*Section 2.* The council shall be empowered to elect from time to time as honorary officers or fellows of the Society persons of eminence in the field of mineralogy, or some closely allied science, who shall serve for life.

Article IV. Membership.

*Section 1.* The general membership of the Society shall be composed of fellows, members, and patrons. There may also be correspondents.

*Section 2.* Fellows shall be persons who have published results of research in mineralogy, crystallography, or allied sciences, and who upon nomination by the council shall have been duly elected to fellowship in the Society.

*Section 3.* Members shall be persons not fellows who are engaged or interested in mineralogy, crystallography, or allied sciences.

*Section 4.* Patrons shall be persons who have bestowed important favors upon the Society. Election to patronship carries with it the rights and privileges of members.

*Section 5.* Fellows, members, and patrons shall be entitled to vote in the transaction of the regular business of the Society. Only fellows are eligible to office in the Society.

*Section 6.* Correspondents shall be persons distinguished for their attainments in mineralogy, crystallography, or allied sciences and not resident in North America.

Article V. Amendments.

This constitution shall be amended when the proposed amendment is favored by four-fifths of all the fellows voting upon it. A copy of the proposed amendment shall be published in the journal of the Society at least three months before the annual meeting. Voting shall be by mail ballot.

AMENDMENTS TO THE CONSTITUTION

Article II. Object.

The object of this Society shall be the advancement of mineralogy, crystallography, *petrography* and allied sciences.

Article IV. Membership.

*Section 2.* Fellows shall be persons who have published results of research on mineralogy, crystallography, *petrography* or allied sciences, and who upon nomination by the Council shall have been duly elected to fellowship in the Society.

*Section 2a.* Outstanding scientists of recognized scientific accomplishments in the field of mineralogy, crystallography, petrography, and allied sciences, who are members of other scientific societies in the field of geology, such as the Geological Society of America, Society of Economic Geologists, American Institute of Mining and Metallurgical Engineers, the American Association of Petroleum Geologists, and other similar scientific societies, may be nominated for *fellowship* in the Society upon recommendation of the Council.

*Section 4.* Patrons shall be persons who have bestowed important favors upon the Society. Election to patronship carries with it the rights and privileges of *fellows*.

#### BY-LAWS

##### Article I. Membership.

*Section 1. Eligibility.* Any person who has, in the opinion of the council, contributed materially to the advancement of mineralogy, crystallography, or allied sciences, shall be eligible for fellowship in the Society. Any person or corporation interested in mineralogy, crystallography, or allied sciences shall be eligible to membership.

*Section 2. Election.* (a) *Fellows.* Nomination for fellowship must be made by two fellows according to a form to be provided by the council. One of these fellows must be personally acquainted with the nominee and his qualifications. The council will submit the nominations received by them, if approved, to a vote of the fellows in the manner provided in the By-Laws. The result may be announced at any stated meeting, after which notice shall be sent to the elected.

(b) *Members.* Nominations for membership must be made on blanks provided by the council, and receive the endorsement of the secretary and treasurer of the Society.

*Section 3. Termination.* Membership in the Society may be terminated or the names of the members may be placed upon the inactive list by vote of the council.

##### Article II. Dues.

*Section 1.* No person shall be accepted as a fellow of the Mineralogical Society of America unless he pays dues for the year within three months after notification of his election. The annual dues for fellows shall be five dollars (\$5), payable at or before the annual meeting in advance.

*Section 2.* The annual dues for members shall be three dollars (\$3). No person shall be accepted as a member unless he pays the dues for the year within three months after notification of his election. The annual dues shall be payable at or before the annual meeting in advance.

*Section 3.* An arrearage in payment of annual dues of four months shall deprive a fellow or member of the privilege of taking part in the management of the Society and of receiving the publications of the Society. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.

*Section 4.* A single prepayment of one hundred dollars (\$100) shall be accepted as commutation for life for either fellows or members. In the case of fellows, who are also fellows of the Geological Society of America, a single prepayment of fifty dollars (\$50) shall be accepted as commutation for life.

*Section 5.* Any person eligible under Article IV of the Constitution may be elected patron upon the payment of one thousand dollars (\$1000) to the Society.

##### Article III. Duties of Officers.

*Section 1. Officers.* The duties of the president, vice-president, treasurer, secretary, and editor of the Society shall be the usual ones performed by such officers.

*Section 2. Executive Council.* The executive council shall direct all affairs and activities of the Society not otherwise provided for by the Constitution, as well as perform those duties specifically assigned to it.

*Section 3. Committees.* The president shall appoint, with the approval of the council, such committees as may further the objects of the Society, including a board of associate editors. The treasurer, the secretary, the editor, and the chairmen of the various committees shall make formal reports to the Society at least once a year.

#### Article IV. Election of Officers and Fellows.

*Section 1.* Nominations for office shall be made by the council. The list shall be published in the journal of the Society at least three months before the annual meeting. Any ten (10) fellows or members may forward to the secretary other nominations for any or all offices. All such nominations reaching the secretary not later than November 1 shall be printed, together with the names of the nominators as special ballots. The regular and special ballots shall then be mailed to the general membership. The results shall be announced at the annual meeting, and the officers thus elected shall enter upon duty at the adjournment of the meeting.

*Section 2.* The list of nominations for fellowships in the Society shall be sent to the fellows at the same time as the nominations for officers. Five opposing votes shall be considered as rendering a candidate ineligible for fellowship.

#### Article V. Publications.

The Society shall publish a journal devoted to the advancement of mineralogy, crystallography, and allied sciences. The general membership of the Society shall be entitled to receive the journal.

#### Article VI. Affiliation with other Scientific Organizations.

The council shall have the authority to arrange for affiliation with other scientific organizations and, as occasion may arise to appoint fellows to represent the Society on the councils of such organizations. In the case of the Geological Society of America, the representative so appointed shall also be a fellow of the Geological Society of America, and shall be recommended to the council of said society for confirmation as one of its nominees for the vice-presidency.

#### Article VII. Local Sections.

Local sections of the Society may be formed in any locality, with the advice and consent of the council, for the purpose of holding meetings and promoting cooperation. The affairs of such local sections shall be entirely in their own hands.

#### Article VIII. Meetings.

There shall be an annual meeting of the Society and such other meetings as may be called by the council. The annual meeting shall be held, whenever practicable, at the same time and place as that of the Geological Society of America.

#### Article IX. Revision of the By-Laws.

After recommendation by the council, By-Laws may be enacted, amended, or suspended by a two-thirds vote, by ballot, of the general membership of the Society.



## CHANGES IN THE BY-LAWS

## Article I. Membership.

*Section 1. . . . Any person or corporation interested in mineralogy, crystallography, petrography or allied sciences, shall be eligible to membership.*

*Section 2. Election. (a) Fellows. . . .*

*(b) Members. Candidates for membership in the Mineralogical Society of America should be endorsed by at least one fellow of the Society and the application approved by either the secretary or treasurer acting for the Council.*

## Article II. Dues.

*Section 1. . . . The annual dues for fellows of the Mineralogical Society of America who also pay dues as fellows of the Geological Society of America shall be two dollars (\$2.00) payable at or before the annual meeting in advance. This provision shall continue in effect as long as the Geological Society of America shall contribute funds which the Council of the Mineralogical Society of America shall consider adequate to assist in publication of the Journal of the Mineralogical Society of America.*

## Article V. Publications.

The Society shall publish a journal devoted to the advancement of mineralogy, crystallography, *petrography* and allied sciences.

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## CORRESPONDENTS OF THE MINERALOGICAL SOCIETY OF AMERICA

- Brauns, Reinhard, University of Bonn, Germany.  
Brøgger, Waldemar, University of Oslo, Oslo, Norway.  
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Niggli, Paul, Eidgenössische Technische Hochschule, Zurich, Switzerland.  
Slavik, Frantisek, Karlova Univ. mineral ustav. Albertov 6, Praha VI, CSR.  
Spencer, L. J., Curator of Minerals, British Museum, South Kensington S.W. 7, London, England.

## FELLOWS AND MEMBERS OF THE MINERALOGICAL SOCIETY OF AMERICA<sup>1</sup>

(\*Indicates Fellow)

- \*Adams, Elliot Q., Lamp Development Laboratory, Nela Park, Cleveland, Ohio.  
Adams, John Wagstaff, 1414 Washington Ave., Golden, Colorado.  
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Bain, George W., 12 Dana St., Amherst, Massachusetts.  
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Baker, V. G., Norman, Arkansas.

<sup>1</sup> This list is as of January 1, 1937. Omissions or corrections should be sent to the Secretary, Paul F. Kerr, Dept. of Geology, Columbia University, New York, N.Y.

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- \*Campbell, Ian, Dept. of Geology, California Institute of Technology, Pasadena, California.
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## TEACHING FELLOWSHIP IN MINERALOGY

A teaching fellowship in mineralogy has been established at Stanford University. This fellowship is open to graduate students who intend to specialize in mineralogy, and preference will be given to those who have had one or two years of graduate work. The chief duty of the fellow is to assist in laboratory instruction. Not more than eight or nine hours work a week will be required. The amount of the fellowship is \$750.

Application for the year 1937-38, accompanied by testimonial letters, should be made to Professor Austin F. Rogers, Box 87, Stanford University, California.

Dr. Reinhard Brauns, Professor Emeritus of Mineralogy and Petrography at the University of Bonn, Germany, was struck by a street car and fatally injured. He died on January 30, 1937, at the age of 75 years. Dr. Brauns was one of the Correspondents of the Mineralogical Society of America. A memorial will be published at a later date.